



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : C12N 15/82, 15/55, 15/52, 15/54, 9/12, 9/16, 9/90, C07K 16/40, C12N 1/10, A01H 5/00		A1	(11) International Publication Number: WO 99/05298 (43) International Publication Date: 4 February 1999 (04.02.99)
(21) International Application Number: PCT/US98/14657		(71) Applicant (for all designated States except US): PIONEER HI-BRED INTERNATIONAL, INC. [US/US]; 800 Capital Square, 400 Locust Street, Des Moines, IA 50309 (US).	
(22) International Filing Date: 17 July 1998 (17.07.98)		(72) Inventors; and (75) Inventors/Applicants (for US only): MARTINO-CATT, Susan, J. [US/US]; 499 N.W. 69th Place, Ankeny, IA 50021 (US). WANG, Hongyu [CN/US]; 8008 Oakwood Drive, Urbandale, IA 50322 (US). BEACH, Larry, R. [US/US]; 3939 Maquoketa Drive, Des Moines, IA 50311 (US). BOWEN, Benjamin, A. [GB/US]; 3008 36th Street, Des Moines, IA 50310 (US). WANG, Xun [CN/US]; 12524 Caminito Vista Soledad, San Diego, CA 92130 (US).	
(30) Priority Data: 60/053,371 22 July 1997 (22.07.97) US 60/053,944 28 July 1997 (28.07.97) US 60/055,526 8 August 1997 (08.08.97) US 60/055,446 11 August 1997 (11.08.97) US 60/085,852 18 May 1998 (18.05.98) US		(74) Agents: MICHEL, Marianne, H. et al.; 7100 N.W. 62nd Avenue, Darwin Building, Johnston, IA 50131 (US).	
(63) Related by Continuation (CON) or Continuation-in-Part (CIP) to Earlier Applications US 60/053,371 (CIP) Filed on 22 July 1997 (22.07.97) US 60/053,944 (CIP) Filed on 28 July 1997 (28.07.97) US 60/055,526 (CIP) Filed on 8 August 1997 (08.08.97) US 60/055,446 (CIP) Filed on 11 August 1997 (11.08.97) US 60/085,852 (CIP) Filed on 18 May 1998 (18.05.98)		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).	
		Published <i>With international search report.</i>	

(54) Title: GENES CONTROLLING PHYTATE METABOLISM IN PLANTS AND USES THEREOF

(57) Abstract

This invention relates to newly identified polynucleotides and polypeptides, variants and derivatives of same; methods for making the polynucleotides, polypeptides, variants, derivatives and antagonists. In particular the invention relates to polynucleotides and polypeptides of the phytate metabolic pathway.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		

GENES CONTROLLING PHYTATE METABOLISM
IN PLANTS AND USES THEREOF

5

Field of the Invention

The present invention relates to the field of animal nutrition. Specifically, the present invention relates to the identification and use of genes encoding various enzymes involved in the metabolism of phytate in plants and the use of these genes and mutants thereof to reduce the levels of phytate, and/or increase the levels of 10 non-phytate phosphorus in food or feed.

15

Background of the Invention

The role of phosphorus in animal nutrition is well recognized. Eighty percent of the phosphorus in the body of animals is found in the skeleton, providing 20 structure to the animal. Twenty percent of the phosphorus in animals can be found in soft tissues, where it is a constituent compound and therefore involved in a wide series of biochemical reactions. For example, phosphorus is required for the synthesis and activity of DNA, RNA, phospholipids, and some B vitamins.

25

Though phosphorus is essential for healthy animals, it is also recognized that not all phosphorus in feed is bioavailable. Phytic acid salts (i.e., phytates) are the major storage form of phosphorus in plants. See e.g., "Chemistry and Application of Phytic Acid: an Overview," Phytic Acid: Chemistry and Application; Graf, Ed.; Pilatus Press: Minneapolis, MN, pp. 1-21; (1986). Phytates are the major form of phosphorus in seeds, typically representing from 50% to 80% of seed total phosphorus.

30

In corn and soybeans, for example, phytate represents about 60% to 80% of total phosphorus. When seed-based diets are consumed by non-ruminants, the consumed phytic acid forms salts with several nutritionally-important minerals in the intestinal tract. Excretion of these salts reduces the retention and utilization, i.e., bioavailability of the diet's phosphorus and mineral contents. Consequently, this can result in mineral deficiencies in both humans and animals fed the above seed.

See e.g., McCance, et al., Biochem. J., 29:4269 (1935); Edman, Cereal Chem., 58:21 (1981).

Phytate, a large source of phosphorus, is not metabolized by monogastric animals. Phytic acid, in fact, is considered to be an anti-nutritional factor because it 5 reduces the bioavailability of proteins and minerals by chelation; see e.g., Cheryan, "Phytic Acid Interactions in Food Systems," CRC Crit. Rev. Food Sci. Nutr., 13:297-335 (1980).

Phytate does not simply cause a reduction in nutrient availability. The phytate-bound phosphorus in animal waste contributes to surface and ground water 10 pollution. See e.g., Jongbloed, et al., Nether. J. Ag. Sci. 38:567 (1990).

Because the phytate content of seed has an impact on diet, phosphorus and mineral retention, and the environment, several approaches have been proposed to reduce this impact. Approaches include removing dietary phytate by post-harvest intervention and reducing seed phytate content genetically.

15 Post-harvest food processing methods that remove phytic acid either physically or via fermentation, are disclosed for example by Indumadhavi, et al., Int. J. Food Sci. Tech. 27:221 (1992). Hydrolyzing phytic acid is a useful approach to increase the nutritional value of many plant foodstuffs. Phytases, as discussed more fully below, catalyze the conversion of phytic acid to inositol and inorganic 20 phosphate. Phytase-producing microorganisms include bacteria and yeasts. See e.g. Power, et al., J. Bacteriol. 151:1102-1108 (1982); Segueilha, et al., Biotechnol. Lett. 15(4):399-404 (1993) and Nayini, et al., Lebensm. Wiss. Technol. 17: 24-26 (1984).

25 The use of phytases, phytic acid-specific phosphohydrolases, typically of microbial origin, as dietary supplements, is disclosed by Nelson, et al., J. Nutr. 101:1289 (1971). All currently known post-harvest technologies involve added procedures and expense in order to circumvent problems associated with phytate.

30 The genetic approach involves developing crop germplasm possessing heritable reductions in seed phytic acid. Heritable quantitative variation in seed phytic acid has been observed among lines of several crop species. See Raboy, In:

Inositol Metabolism in Plants, Moore D.J., et al., (eds.) Alan R. Liss, New York, pp. 52-73; (1990).

However, this variation has been found to be highly and positively correlated with variation in less desirable characteristics, therefore, breeding for reduced seed 5 phytic acid using traditional breeding methods, could result in germplasm with undesirable correlated characteristics. To date, there have been no reports of commercially acceptable low phytic acid corn germplasm produced by such an approach.

In genetically altering phytate, natural variability for phytate and free 10 phosphorus has been examined. See Raboy, V. and D.B. Dickinson Crop Sci. 33:1300-1305 (1993), and Raboy, V. et al., Maydica 35:383-390(1990). While some variability for phytic acid was observed, there was no corresponding change in non- phytate phosphorus. In addition, varietal variability represented only two percent of the variation observed, whereas ninety-eight percent of the variation in phytate was 15 attributed to environmental factors.

As mentioned above, studies of soybean and other crops have indicated that altering genetic expression of phytate through recurrent selection breeding methods might have correlated undesirable results. See Raboy, V., D.B. Dickinson, and F.E. Below; Crop Sci. 24:431-434 (1984); Raboy, V., F.E. Below, and D.B. Dickinson; J. Hered. 80:311-315 (1989); Raboy, V., M.M. Noaman, G.A. Taylor, and S.G. Pickett; Crop Sci. 31: 631-635; (1991).

While it has been proposed that a block in phytic acid accumulation might be valuable in producing low phytic acid germplasm without the introduction of undesirable correlated responses, (See Raboy, et al., Crop Sci. 33: 1300 (1993)) 25 employing such a traditional mutant selection approach has, in certain cases, revealed that homozygosity for mutants associated with substantial reductions in phytic acid also proved to be lethal.

Myo-inositol is produced from glucose in three steps involving the enzymes hexokinase (EC 2.7.1.1), L-myoinositol 1-phosphate synthase (EC 5.5.1.4) and L- 30 myoinositol 1-phosphate phosphatase (EC 3.1.3.25). The biosynthetic route leading to phytate is complex and not completely understood. Without wishing to be

bound by any particular theory of the formation of phytate, it is believed that the synthesis may be mediated by a series of one or more ADP-phosphotransferases, ATP-dependent kinases and isomerase. A number of intermediates have been isolated including for example 2 and 3 monophosphates, 1,3 and 2,6 di-phosphates, 5 1,3,5 and 2,5,6 triphosphates, 1,3,5,6 and 2,3,5,6 tetra-phosphates, and 1,2,4,5,6 and 1,2,3,4,6 penta-phosphates. Several futile cycles of dephosphorylation and rephosphorylation of the P_5 and P_6 forms have been reported as well as a cycle involving $G6P \rightarrow$ myoinositol-1-phosphate \rightarrow myo-inositol; the last step being completely reversible, indicating that control of metabolic flux through this pathway 10 may be important. This invention differs from the foregoing approaches in that it provides tools and reagents that allows the skilled artisan, by the application of, *inter alia*, transgenic methodologies to influence the metabolic flux in respect to the phytic acid pathway. This influence may be either anabolic or catabolic, by which is meant the influence may act to decrease the flow resulting from the biosynthesis of 15 phytic acid and/or increase the degradation (i.e., catabolism of phytic acid). A combination of both approaches is also contemplated by this invention.

As mentioned above, once formed phytate may be dephosphorylated by phosphohydrolases, particularly 3-phytases typically found in microorganisms and 6-phytases the dominant form in plants. After the initial event, both enzymes are 20 capable of successive dephosphorylation of phytate to free inositol.

Accordingly, there have also been reports that plants can be transformed with constructs comprising a gene encoding phytase. See Pen, *et al.*, PCT Publication WO 91/14782, incorporated herein in its entirety by reference. Transgenic seed or plant tissues expressing phytases can then be used as dietary 25 supplements. However, this application has not been done to reduce seed phytic acid.

Based on the foregoing, there exists the need to improve the nutritional content of plants, particularly corn and soybean by increasing non-phytate phosphorus and reducing seed phytate with no other obvious or substantial adverse 30 effects.

Summary of the Invention

It is therefore an object of the present invention to provide plants, particularly transgenic corn, which has enhanced levels of non-phytate phosphorus without corresponding detrimental effects.

5 It is a further object of the present invention to provide plants, particularly transgenic corn which have reduced levels of phosphorus in the form of phytate without corresponding detrimental effects.

10 It is a further object of the present invention to provide transgenic plant lines with dominant, heritable phenotypes which are useful in breeding programs designed to produce commercial products with improved phosphorus availability and reduced phytate.

15 It is a further object of the present invention to improve animal performance by feeding animals plants and parts thereof particularly seeds with enhanced nutritional value.

20 It is a further object of the present invention to provide plant seeds, particularly corn seeds and resulting meal, that result in less environmental contamination, when excreted, than do currently used seeds.

These and other objects of the invention will become readily apparent from the ensuing description.

25 20 An isolated polynucleotide is provided comprising a member selected from the group consisting of:

- (a) a polynucleotide encoding a polypeptide comprising SEQ ID NOS: 2, 6, 11, 17 or complement thereof;
- (b) a polynucleotide of at least 25 nucleotides in length which selectively hybridizes under stringent conditions to a polynucleotide of SEQ ID NOS: 1, 5, 7, 10, 14, 15, 16 or a complement thereof, wherein the hybridization conditions include a wash step in 0.1X SSC at 60°C;
- (c) a polynucleotide having a sequence of a nucleic acid amplified from a *Zea mays* nucleic acid library using the primers of SEQ ID NOS: 3-4, 8-9, 12-13, 30 or 18-19;

5 (d) a polynucleotide having at least 75% sequence identity to SEQ ID NO: 1, at least 60% sequence identity to SEQ ID NO: 5, at least 80% sequence identity to SEQ ID NO: 10, or at least 70% sequence identity to SEQ ID NO: 16, wherein the % sequence identity is based on the entire coding region and is determined by the GAP program where the gap creation penalty = 50 and the gap extension penalty = 3; and

10 (e) a polynucleotide comprising at least 20 contiguous bases of the polynucleotide of (a) through (c), or complement thereof.

15 According to the present invention, polypeptides that have been identified as novel phytate biosynthetic enzymes are provided.

20 An isolated polypeptide is provided comprising an amino acid sequence which has at least 80% sequence identity to SEQ ID NO: 2, at least 35% sequence identity to SEQ ID NO: 6, at least 90% sequence identity to SEQ ID NO: 11 or at least 80% sequence identity to SEQ ID NO: 17, wherein the % sequence identity is based on the entire sequence and is determined by the GAP program where the gap creation penalty = 12 and the gap extension penalty = 4.

25 It is a further object of the invention, moreover, to provide polynucleotides that encode maize phytate biosynthetic enzymes, particularly polynucleotides that encode phosphatidylinositol 3-kinase, myo-inositol monophosphatase-3, myo-inositol 1,3,4-triphosphate 5/6 kinase and myo-inositol 1-phosphate synthase.

30 In a particularly preferred embodiment of this aspect of the invention the polynucleotide comprises the regions encoding phosphatidylinositol 3-kinase, myo-inositol monophosphatase-3, myo-inositol 1,3,4-triphosphate 5/6 kinase and myo-inositol 1-phosphate synthase.

35 In another particularly preferred embodiment of the present invention polypeptides are isolated from *Zea mays*.

40 In accordance with this aspect of the present invention there is provided a polynucleotide of at least 25 nucleotides in length which selectively hybridizes under stringent conditions to the polynucleotides set out below, or a complement thereof.

45 As used herein, "stringent conditions" means the hybridization conditions include a wash step in 0.1X SSC at 60°C.

In accordance with this aspect of the present invention there is provided a polynucleotide having a sequence of a nucleic acid amplified from a *Zea mays* nucleic acid library using the primers set out in the sequences below.

In accordance with this aspect of the invention there are provided isolated 5 nucleic acid molecules encoding phytate biosynthetic enzymes, particularly those from *Zea mays*, mRNAs, cDNAs, genomic DNAs and, in further embodiments of this aspect of the invention, biologically, useful variants, analogs or derivatives thereof, or fragments thereof, including fragments of the variants, analogs and derivatives.

Other embodiments of the invention are naturally occurring allelic variants of the 10 nucleic acid molecules in the sequences provided which encode phytate biosynthetic enzymes.

In accordance with another aspect of the invention there are provided novel 15 polypeptides which comprise phytate biosynthetic enzymes of maize origin as well as biologically, or diagnostically useful fragments thereof, as well as variants, derivatives and analogs of the foregoing and fragments thereof.

It also is an object of the invention to provide phytate biosynthetic polypeptides, particularly phosphatidylinositol 3-kinase, myo-inositol monophosphatase-3, myo-inositol 1,3,4-triphosphate 5/6 kinase or myo-inositol 1-phosphate synthase polypeptide, that may be employed for modulation of phytic acid synthesis.

20 In accordance with yet a further aspect of the present invention, there is provided the use of a polypeptide of the invention, or particular fragments thereof.

It is another object of the invention to provide a process for producing the polypeptides, polypeptide fragments, variants and derivatives, fragments of the variants and derivatives, and analogs of the foregoing.

25 In a preferred embodiment of this aspect of the invention there are provided methods for producing the polypeptides comprising culturing host cells having expressibly incorporated therein a polynucleotide under conditions for expression of phytate biosynthetic enzymes in the host and then recovering the expressed polypeptide.

In accordance with another object of the invention there are provided products, compositions, processes and methods that utilize the aforementioned polypeptides and polynucleotides, for purposes including research, biological, and agricultural.

In accordance with yet another aspect of the present invention, there are 5 provided inhibitors to such polypeptides, useful for modulating the activity and/or expression of the polypeptides. In particular, there are provided antibodies against such polypeptides.

In accordance with certain embodiments of the invention there are probes that hybridize to phytate biosynthetic enzyme polynucleotide sequences useful as molecular 10 markers in breeding programs.

In certain additional preferred embodiments of this aspect of the invention there are provided antibodies against the phytate biosynthetic enzymes. In certain particularly preferred embodiments in this regard, the antibodies are selective for the entire class the phytate biosynthetic enzymes, irrespective of species of origin as well 15 as species-specific antibodies, such as antibodies capable of specific immune reactivity with for example, *Zea mays* phytate biosynthetic enzymes.

In accordance with yet another aspect of the present invention, there are provided phytate enzyme antagonists. Among preferred antagonists are those which bind to phytate biosynthetic enzymes so as to inhibit the binding of binding molecules or 20 to stabilize the complex formed between the phytate biosynthetic enzyme and the binding molecule to prevent further biological activity arising from the phytate biosynthetic enzyme. Also among preferred antagonists are molecules that bind to or interact with phytate biosynthetic enzymes so as to inhibit one or more effects of a particular phytate biosynthetic enzyme or which prevent expression of the enzyme and 25 which also preferably result in a lowering of phytic acid accumulation.

Other objects, features, advantages and aspects of the present invention will become apparent to those of skill from the following description. It should be understood, however, that the following description and the specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only. 30 Various changes and modifications within the spirit and scope of the disclosed invention

will become readily apparent to those skilled in the art from reading the following description and from reading the other parts of the present disclosure.

Detailed Description of the Invention

5 This application claims priority under 35 U.S.C. 120 to U.S. Ser. Nos. 60/053,371 filed July 18, 1997; 60/053,944 filed July 28, 1997; 60/055,526 filed August 8, 1997; 60/055,446 and 60/085,852 filed May 18, 1998 the disclosures of which are incorporated herein by reference.

10 This invention relates, in part, to newly identified polynucleotides and polypeptides; variants and derivatives of these polynucleotides and polypeptides; processes for making these polynucleotides and these polypeptides, and their variants and derivatives and antagonists of the polypeptides; and uses of these polynucleotides, polypeptides, variants, derivatives and antagonists. In particular, in these and in other regards, the invention relates to polynucleotides and polypeptides of the phytate 15 metabolic pathway, most particularly with the enzymes phosphatidylinositol 3-kinase, myo-inositol monophosphatase-3, myo-inositol 1,3,4-triphosphate 5/6 kinase and myo-inositol 1-phosphate synthase and genes encoding same.

Glossary

20 The following illustrative explanations are provided to facilitate understanding of certain terms used frequently herein, particularly in the Examples. The explanations are provided as a convenience and are not limitative of the invention.

25 **PHYTATE BIOSYNTHETIC ENZYME-BINDING MOLECULE**, as used herein, refers to molecules or ions which bind or interact specifically with phytate biosynthetic enzyme polypeptides or polynucleotides of the present invention, including, for example enzyme substrates, cell membrane components and classical receptors. Binding between polypeptides of the invention and such molecules, including binding or interaction molecules may be exclusive to polypeptides of the invention, which is preferred, or it may be highly specific for polypeptides of the invention, which is also preferred, or it may be highly specific to a group of proteins that includes polypeptides of the invention, which is preferred, or it may be specific to several groups of proteins at

least one of which includes a polypeptide of the invention. Binding molecules also include antibodies and antibody-derived reagents that bind specifically to polypeptides of the invention.

GENETIC ELEMENT, as used herein, generally means a polynucleotide 5 comprising a region that encodes a polypeptide or a polynucleotide region that regulates replication, transcription or translation or other processes important to expression of the polypeptide in a host cell, or a polynucleotide comprising both a region that encodes a polypeptide and a region operably linked thereto that regulates expression. Genetic elements may be comprised within a vector that replicates as an 10 episomal element; that is, as a molecule physically independent of the host cell genome. They may be comprised within plasmids. Genetic elements also may be comprised within a host cell genome; not in their natural state but, rather, following manipulation such as isolation, cloning and introduction into a host cell in the form of purified DNA or in a vector, among others.

HOST CELL, as used herein, is a cell which has been transformed or 15 transfected, or is capable of transformation or transfection by an exogenous polynucleotide sequence. Exogenous polynucleotide sequence is defined to mean a sequence not naturally in the cell. This includes transformation to incorporate additional copies of an endogenous polynucleotide.

IDENTITY and SIMILARITY, as used herein, and as known in the art, are 20 relationships between two polypeptide sequences or two polynucleotide sequences, as determined by comparing the sequences. In the art, identity also means the degree of sequence relatedness between two polypeptide or two polynucleotide sequences as determined by the match between two strings of such sequences. Both identity and 25 similarity can be readily calculated (*Computational Molecular Biology*, Lesk, A.M., ed., Oxford University Press, New York, 1988; *Biocomputing: Informatics and Genome Projects*, Smith, D.W., ed., Academic Press, New York, 1993; *Computer Analysis of Sequence Data*, Part I, Griffin, A.M., and Griffin, H.G., eds., Humana Press, New Jersey, 1994; *Sequence Analysis in Molecular Biology*, von Heijne, G., 30 Academic Press, 1987; and *Sequence Analysis Primer*, Gribskov, M. and Devereux, J., eds., M Stockton Press, New York, 1991). Methods commonly employed to

determine identity or similarity between two sequences include, but are not limited to those disclosed in Carillo, H., and Lipman, D., SIAM J. Applied Math., 48:1073 (1988). Preferred methods to determine identity are designed to give the largest match between the two sequences tested. Methods to determine identity and 5 similarity are codified in computer programs. Typical computer program methods to determine identity and similarity between two sequences include, GCG program package (Devereux, J., et al., Nucleic Acids Research 12(1): 387 (1984)), BLASTP, BLASTN, FASTA and TFASTA (Atschul, S.F. et al., J. Mol. Biol. 215: 403 (1990)).

For purposes of defining the present invention, the Gap program is used. 10 The algorithm used for the Gap program is that of Needleman and Wunsch (J. Mol. Biol. 48: 443-453 [1970]). The parameters used are as follows: for nucleotide comparisons the gap creation penalty = 50, gap extension penalty = 3; for amino acid comparisons the gap creation penalty = 12, the gap extension penalty = 4.

ISOLATED, as used herein, means altered "by the hand of man" from its natural 15 state; i.e., that, if it occurs in nature, it has been changed or removed from its original environment, or both. For example, a naturally occurring polynucleotide or a polypeptide naturally present in a living organism in its natural state is not "isolated," but the same polynucleotide or polypeptide separated from the coexisting materials of its natural state is "isolated", as the term is employed herein. For example, with respect to 20 polynucleotides, the term isolated means that it is separated from the chromosome and cell in which it naturally occurs. As part of or following isolation, such polynucleotides can be joined to other polynucleotides, such as DNAs, for mutagenesis, to form fusion proteins, and for propagation or expression in a host, for instance. The isolated polynucleotides, alone or joined to other polynucleotides such as vectors, can be 25 introduced into host cells, in culture or in whole organisms. Introduced into host cells in culture or in whole organisms, such DNAs still would be isolated, as the term is used herein, because they would not be in their naturally occurring form or environment. Similarly, the polynucleotides and polypeptides may occur in a composition, such as media formulations, solutions for introduction of polynucleotides or polypeptides, for 30 example, into cells, compositions or solutions for chemical or enzymatic reactions, for

instance, which are not naturally occurring compositions, and, therein remain isolated polynucleotides or polypeptides within the meaning of that term as it is employed herein.

LIGATION, as used herein, refers to the process of forming phosphodiester bonds between two or more polynucleotides, which most often are double stranded 5 DNAs. Techniques for ligation are well known to the art and protocols for ligation are described in standard laboratory manuals and references, such as, for instance, Sambrook *et al.*, *MOLECULAR CLONING, A LABORATORY MANUAL*, 2nd Ed.; Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York (1989) and Maniatis *et al.*, pg. 146, as cited below.

OLIGONUCLEOTIDE(S) , as used herein, refers to short polynucleotides. Often 10 the term refers to single-stranded deoxyribonucleotides, but it can refer as well to single- or double-stranded ribonucleotides, RNA:DNA hybrids and double-stranded 15 DNAs, among others. Oligonucleotides, such as single-stranded DNA probe oligonucleotides, often are synthesized by chemical methods, such as those implemented on automated oligonucleotide synthesizers. However, oligonucleotides 20 can be made by a variety of other methods, including *in vitro* recombinant DNA-mediated techniques and by expression of DNAs in cells and organisms. Initially, chemically synthesized DNAs typically are obtained without a 5' phosphate. The 5' 25 ends of such oligonucleotides are not substrates for phosphodiester bond formation by ligation reactions that employ DNA ligases typically used to form recombinant DNA molecules. Where ligation of such oligonucleotides is desired, a phosphate can be added by standard techniques, such as those that employ a kinase and ATP. The 3' end of a chemically synthesized oligonucleotide generally has a free hydroxyl group and, in the presence of a ligase, such as T4 DNA ligase, readily will form a phosphodiester bond with a 5' phosphate of another polynucleotide, such as another 30 oligonucleotide. As is well known, this reaction can be prevented selectively, where desired, by removing the 5' phosphates of the other polynucleotide(s) prior to ligation.

PLASMIDS, as used herein, generally are designated herein by a lower case p preceded and/or followed by capital letters and/or numbers, in accordance with 30 standard naming conventions that are familiar to those of skill in the art. Starting plasmids disclosed herein are either commercially available, publicly available, or can

be constructed from available plasmids by routine application of well known, published procedures. Many plasmids and other cloning and expression vectors that can be used in accordance with the present invention are well known and readily available to those of skill in the art. Moreover, those of skill readily may construct any number of other 5 plasmids suitable for use in the invention. The properties, construction and use of such plasmids, as well as other vectors, in the present invention will be readily apparent to those of skill from the present disclosure.

POLYNUCLEOTIDE(S), as used herein, generally refers to any polyribonucleotide or polydeoxribonucleotide, which may be unmodified RNA or DNA or 10 modified RNA or DNA. Thus, for instance, polynucleotides as used herein refers to, among others, single-and double-stranded DNA, DNA that is a mixture of single- and double-stranded regions or single-, double- and triple-stranded regions, single- and double-stranded RNA, and RNA that is mixture of single- and double-stranded regions, hybrid molecules comprising DNA and RNA that may be single-stranded or, more 15 typically, double-stranded, or triple-stranded, or a mixture of single- and double-stranded regions. In addition, polynucleotide as used herein refers to triple-stranded regions comprising RNA or DNA or both RNA and DNA. The strands in such regions may be from the same molecule or from different molecules. The regions may include all of one or more of the molecules, but more typically involve only a region of some of 20 the molecules. One of the molecules of a triple-helical region often is an oligonucleotide. As used herein, the term polynucleotide includes DNAs or RNAs as described above that contain one or more modified bases. Thus, DNAs or RNAs with backbones modified for stability or for other reasons are "polynucleotides" as that term is intended herein. Moreover, DNAs or RNAs comprising unusual bases, such as 25 inosine, or modified bases, such as tritylated bases, to name just two examples, are polynucleotides as the term is used herein. It will be appreciated that a great variety of modifications have been made to DNA and RNA that serve many useful purposes known to those of skill in the art. The term polynucleotide as it is employed herein embraces such chemically, enzymatically or metabolically modified forms of 30 polynucleotides, as well as the chemical forms of DNA and RNA characteristic of viruses and cells, including *inter alia*, simple and complex cells.

POLYPEPTIDES, as used herein, includes all polypeptides as described below. The basic structure of polypeptides is well known and has been described in innumerable textbooks and other publications in the art. In this context, the term is used herein to refer to any peptide or protein comprising two or more amino acids joined to each other in a linear chain by peptide bonds. As used herein, the term refers to both short chains, which also commonly are referred to in the art as peptides, oligopeptides and oligomers, for example, and to longer chains, which generally are referred to in the art as proteins, of which there are many types. It will be appreciated that polypeptides often contain amino acids other than the 20 amino acids commonly referred to as the 20 naturally occurring amino acids, and that many amino acids, including the terminal amino acids, may be modified in a given polypeptide, either by natural processes, such as processing and other post-translational modifications, but also by chemical modification techniques which are well known to the art. Even the common modifications that occur naturally in polypeptides are too numerous to list exhaustively here, but they are well described in basic texts and in more detailed monographs, as well as in a voluminous research literature, and they are well known to those of skill in the art. Among the known modifications which may be present in polypeptides of the present are, to name an illustrative few, acetylation, acylation, ADP-ribosylation, amidation, covalent attachment of flavin, covalent attachment of a heme moiety, covalent attachment of a nucleotide or nucleotide derivative, covalent attachment of a lipid or lipid derivative, covalent attachment of phosphatidylinositol, cross-linking, cyclization, disulfide bond formation, demethylation, formation of covalent cross-links, formation of cystine, formation of pyroglutamate, formylation, gamma-carboxylation, glycosylation, GPI anchor formation, hydroxylation, iodination, methylation, myristoylation, oxidation, proteolytic processing, phosphorylation, prenylation, racemization, selenoylation, sulfation, transfer-RNA mediated addition of amino acids to proteins such as arginylation, and ubiquitination. Such modifications are well known to those of skill and have been described in great detail in the scientific literature. Several particularly common modifications, glycosylation, lipid attachment, sulfation, gamma-carboxylation of glutamic acid residues, hydroxylation and ADP-ribosylation, for instance, are described in most basic texts, such as, for instance *PROTEINS* -

STRUCTURE AND MOLECULAR PROPERTIES, 2nd Ed., T. E. Creighton, W. H. Freeman and Company, New York (1993). Many detailed reviews are available on this subject, such as, for example, those provided by Wold, F., *Posttranslational Protein Modifications: Perspectives and Prospects*, pgs. 1-12 in *POSTTRANSLATIONAL COVALENT MODIFICATION OF PROTEINS*, B. C. Johnson, Ed., Academic Press, New York (1983); Seifter *et al.*, *Meth. Enzymol.* 182:626-646 (1990) and Rattan *et al.*, *Protein Synthesis: Posttranslational Modifications and Aging*, *Ann. N.Y. Acad. Sci.* 663: 48-62 (1992). It will be appreciated, as is well known and as noted above, that polypeptides are not always entirely linear. For instance, polypeptides may be branched as a result of ubiquitination, and they may be circular, with or without branching, generally as a result of posttranslation events, including natural processing event and events brought about by human manipulation which do not occur naturally. Circular, branched and branched circular polypeptides may be synthesized by non-translation natural process and by entirely synthetic methods, as well. Modifications can occur anywhere in a polypeptide, including the peptide backbone, the amino acid side-chains and the amino or carboxyl termini. In fact, blockage of the amino or carboxyl group in a polypeptide, or both, by a covalent modification, is common in naturally occurring and synthetic polypeptides and such modifications may be present in polypeptides of the present invention, as well. For instance, the amino terminal residue of polypeptides made in *E. coli* or other cells, prior to proteolytic processing, almost invariably will be N-formylmethionine. During post-translational modification of the peptide, a methionine residue at the NH₂-terminus may be deleted. Accordingly, this invention contemplates the use of both the methionine-containing and the methionine-less amino terminal variants of the protein of the invention. The modifications that occur in a polypeptide often will be a function of how it is made. For polypeptides made by expressing a cloned gene in a host, for instance, the nature and extent of the modifications in large part will be determined by the host cell post-translational modification capacity and the modification signals present in the polypeptide amino acid sequence. For instance, as is well known, glycosylation often does not occur in bacterial hosts such as, for example, *E. coli*. Accordingly, when glycosylation is desired, a polypeptide should be expressed in a glycosylating host,

generally a eukaryotic cell. Similar considerations apply to other modifications. It will be appreciated that the same type of modification may be present in the same or varying degree at several sites in a given polypeptide. Also, a given polypeptide may contain many types of modifications. In general, as used herein, the term polypeptide encompasses all such modifications, particularly those that are present in polypeptides synthesized by expressing a polynucleotide in a host cell.

TRANSFORMATION, as used herein, is the process by which a cell is "transformed" by exogenous DNA when such exogenous DNA has been introduced inside the cell membrane. Exogenous DNA may or may not be integrated (covalently linked) into chromosomal DNA making up the genome of the cell. In prokaryotes and yeasts, for example, the exogenous DNA may be maintained on an episomal element, such as a plasmid. With respect to higher eukaryotic cells, a stably transformed or transfected cell is one in which the exogenous DNA has become integrated into the chromosome so that it is inherited by daughter cells through chromosome replication. This stability is demonstrated by the ability of the eukaryotic cell to establish cell lines or clones comprised of a population of daughter cells containing the exogenous DNA.

VARIANT(S), as used herein, of polynucleotides or polypeptides, as the term is used herein, are polynucleotides or polypeptides that differ from a reference polynucleotide or polypeptide, respectively. Variants in this sense are described below and elsewhere in the present disclosure in greater detail. With reference to polynucleotides, generally, differences are limited such that the nucleotide sequences of the reference and the variant are closely similar overall and, in many regions, identical. As noted below, changes in the nucleotide sequence of the variant may be silent. That is, they may not alter the amino acids encoded by the polynucleotide. Where alterations are limited to silent changes of this type, a variant will encode a polypeptide with the same amino acid sequence as the reference. Also as noted below, changes in the nucleotide sequence of the variant may alter the amino acid sequence of a polypeptide encoded by the reference polynucleotide. Such nucleotide changes may result in amino acid substitutions, additions, deletions, fusions and truncations in the polypeptide encoded by the reference sequence, as discussed below. With reference

to polypeptides generally, differences are limited so that the sequences of the reference and the variant are closely similar overall and, in many regions, identical. A variant and reference polypeptide may differ in amino acid sequence by one or more substitutions, additions, deletions, fusions and truncations, which may be present in any combination.

5 GERMPLASM, as used herein, means a set of genetic entities which may be used in a conventional breeding program to develop new plant varieties.

10 HIGH PHOSPHOROUS TRANSGENIC, as used herein, means an entity which, as a result of recombinant genetic manipulation, produces seed with a heritable decrease in phytic acid percentage and/or increase in non-phytate phosphorous percentage.

15 PHYTIC ACID, as used herein, means myo-inositol tetraphosphoric acid, myo-inositol pentaphosphoric acid and myo-inositol hexaphosphoric acid. As a salt with cations, phytic acid is "phytate".

20 NON-PHYTATE PHOSPHOROUS, as used herein, means total phosphorus minus phytate phosphorous.

25 NON-RUMINANT ANIMAL means an animal with a simple stomach divided into the esophageal, cardia, fundus and pylorus regions. A non-ruminant animal additionally implies a species of animal without a functional rumen. A rumen is a section of the digestive system where feedstuff/food is soaked and subjected to digestion by micro-organisms before passing on through the digestive tract. This phenomenon does not occur in a non-ruminant animal. The term non-ruminant animal includes but is not limited to humans, swine, poultry, cats and dogs.

30 As mentioned above, the present invention relates to novel phytic acid metabolic polypeptides and polynucleotides encoding same, among other things, as described in greater detail below. Among the polypeptides particularly useful for the practice of this invention include but are not limited to D-myo-inositol-3-phosphate synthase, myo-inositol 1-phosphate synthase (otherwise referred to as INO1), phosphatidylinositol-4-phosphate-5-kinase, signaling inositol polyphosphate-5-phosphatase (SIP-110), myo-inositol monophosphatase-3, myo-inositol 1,3,4 triphosphate 5/6 kinase, 1D-myo-inositol trisphosphate 3-kinase B, myo-inositol monophosphatase-1, inositol polyphosphate 5-phosphatase, 1D-myo-inositol trisphosphate 3-kinase,

phosphatidylinositol 3-kinase, phosphatidylinositol 4-kinase, phosphatidylinositol synthase, phosphatidylinositol transfer protein, phosphatidylinositol 4,5-bisphosphate 5-phosphatase, myo-inositol transporter, phosphatidylinositol-specific phospholipase C and maize phytase.

5 The nucleic acids and fragments thereof encoding the above-mentioned enzymes are useful to generate enzyme deficient transgenics. For example, a single gene or gene fragment (or combinations of several genes) may be incorporated into an appropriate expression cassette (using for example the globulin-1 promoter for embryo-preferred expression or the native promoter associated with the enzyme encoding gene) 10 and transformed into corn along with an appropriate selectable marker (such as the herbicide PAT) in such a manner as to silence the expression of the endogenous genes.

Relevant literature describing the application of homology-dependent gene silencing include: Jorgensen, Trends Biotechnol 8 (12):340-344 (1990); Flavell, Proc. 15 Nat'l. Acad. Sci. (USA) 91:3490-3496 (1994); Finnegan et al., Bio/Technology 12: 883-888 (1994); Neuhuber et al., Mol. Gen. Genet. 244:230-241 (1994). Alternatively, another approach to gene silencing can be with the use of antisense technology (Rothstein et al. in Osf. Surv. Plant Mol. Cell. Biol. 6: 221-246 (1989)).

20 In particular, the invention relates to polypeptides and polynucleotides of novel phytate biosynthetic enzyme genes. The invention relates especially to *Zea mays* phytate biosynthetic enzymes having the nucleotide and amino acid sequences set out below respectively.

Polynucleotides

25 In accordance with one aspect of the present invention, there are provided isolated polynucleotides which encode the phytate biosynthetic enzymes having the deduced amino acid sequence below.

30 Using the information provided herein, such as the polynucleotide sequences set out below, a polynucleotide of the present invention encoding phytate biosynthetic enzyme polypeptides may be obtained using standard cloning and screening procedures. To obtain the polynucleotide encoding the protein using the DNA

sequences given below, oligonucleotide primers can be synthesized that are complementary to the known polynucleotide sequence. These primers can then be used in PCR to amplify the polynucleotide from template derived from mRNA or genomic DNA isolated from plant material. The resulting amplified products can then be 5 cloned into commercially available cloning vectors, such as the TA series of vectors from InVitrogen. By sequencing the individual clones thus identified with sequencing primers designed from the original sequence, it is then possible to extend the sequence in both directions to determine the full gene sequence. Such sequencing is performed using denatured double stranded DNA prepared from a plasmid clone. Suitable 10 techniques are described by Maniatis, T., Fritsch, E.F. and Sambrook, J. in MOLECULAR CLONING, A Laboratory Manual (2nd edition 1989 Cold Spring Harbor Laboratory. See Sequencing Denatured Double-Stranded DNA Templates 13.70). Illustrative of the invention, the polynucleotide set out below were assembled from a cDNA library derived for example, from germinating maize seeds.

15 Myo-inositol 1-phosphate synthase of the present invention is structurally related to other proteins of the myo-inositol 1-phosphate synthase family, as shown by comparing the present sequence encoding myo-inositol 1-phosphate synthase with sequences reported in the literature. A preferred DNA sequence is set out below. It contains an open reading frame encoding a protein of about 510 amino acid residues with a deduced molecular 20 weight of about 59.7(Calculated as the number of amino acid residues X 117) kDa. The protein exhibits greatest homology to myo-inositol-1-phosphate synthase. The present myo-inositol 1-phosphate synthase has about 88% identity and about 92% similarity with the amino acid sequence of myo-inositol-1-phosphate synthase from *Mesembryanthemum crystallinum* and 78.7% identity at the nucleic acid level (These percentages are based on 25 comparison of full-length coding sequence only i.e.,ATG through stop codon).

Myo-inositol monophosphatase-3 of the invention is structurally related to other proteins of the myo-inositol monophosphatase-3 family, as shown by comparing the present sequence encoding myo-inositol monophosphatase-3 with that of sequence reported in the literature. A preferred DNA sequence is set out below. It contains an open reading frame 30 encoding a protein of about 267 amino acid residues with a deduced molecular weight of about 31.2 kDa (calculated as the number of amino acid residues X 117). Novel myo-

5 inositol monophosphatase-3 identified by homology between the amino acid sequence set out below and known amino acid sequences of other proteins such as myo-inositol monophosphatase-3 from *Lycopersicum esulentum* with 76.1% identity/81.1% similarity at the amino acid level and 67.9% identity at the nucleic acid level (These percentages are based on comparison of full-length coding sequence only i.e., ATG through stop codon).

10 Myo-inositol 1,3,4-trisphosphate 5/6-kinase of the invention is structurally related to other proteins of the myo-inositol 1,3,4-trisphosphate 5/6-kinase family, as shown by comparing the sequence encoding the present inositol 1,3,4-trisphosphate 5/6-kinase with that of sequence reported in the literature. A preferred DNA sequence is set out below. It contains an open reading frame encoding a protein of about 353 amino acid residues with a deduced molecular weight of about 41.3 kDa (calculated as the number of amino acid residues X 117). The protein exhibits greatest homology to myo-inositol 1,3,4-trisphosphate 5/6-kinase from *Homo sapiens*. myo-inositol 1,3,4-trisphosphate 5/6-kinase below has about 34% identity and about 43.4% similarity with the amino acid sequence of myo-inositol 15 1,3,4-trisphosphate 5/6-kinase from *Homo sapiens*. (The percentages disclosed above are based on comparison of full-length coding sequence only i.e., ATG through stop codon.)

20 A preferred phosphatidylinositol 3-kinase sequence is set out below. It contains an open reading frame encoding a protein of about 803 amino acid residues with a deduced molecular weight of about 94.1 kDa (calculated as the number of amino acid residues X 117). The protein exhibits greatest homology to phosphatidylinositol 3-kinase from *Glycine max*. Homology between amino acid sequences set out in the following sequences and known amino acid sequences of other proteins such as phosphatidylinositol 3-kinase from *Glycine max* with 78% identity/ 84% similarity at the amino acid level and 73% identity at the nucleic acid level (these percentages are based on comparison of full-length coding 25 sequence only i.e., ^ATG through stop codon) based on the Gap program defined below.

30 Polynucleotides of the present invention may be in the form of RNA, such as mRNA, or in the form of DNA, including, for instance, cDNA and genomic DNA obtained by cloning or produced by chemical synthetic techniques or by a combination thereof. The DNA may be double-stranded or single-stranded. Single-stranded DNA may be the coding strand, also known as the sense strand, or it may be the non-coding strand, also referred to as the antisense strand.

The coding sequence which encodes the polypeptide may be identical to the coding sequence of the polynucleotides shown below. It also may be a polynucleotide with a different sequence, which, as a result of the redundancy (degeneracy) of the genetic code, encodes the polypeptides shown below. As discussed more fully below, 5 these alternative coding sequences are an important source of sequences for codon optimization.

Polynucleotides of the present invention which encode the polypeptides listed below may include, but are not limited to the coding sequence for the mature polypeptide, by itself; the coding sequence for the mature polypeptide and additional 10 coding sequences, such as those encoding a leader or secretory sequence, such as a pre-, or pro- or prepro- protein sequence; the coding sequence of the mature polypeptide, with or without the aforementioned additional coding sequences, together with additional, non-coding sequences, including for example, but not limited to non-coding 5' and 3' sequences, such as the transcribed, non-translated sequences that 15 play a role in transcription (including termination signals, for example), ribosome binding, mRNA stability elements, and additional coding sequence which encode additional amino acids, such as those which provide additional functionalities.

The DNA may also comprise promoter regions which function to direct the transcription of the mRNA encoding phytate biosynthetic enzymes of this invention. 20 Such promoters may be independently useful to direct the transcription of heterologous genes in recombinant expression systems. Heterologous is defined as a sequence that is not naturally occurring with the promoter sequence. While the nucleotide sequence is heterologous to the promoter sequence, it may be homologous, or native, or heterologous, or foreign to the plant host.

25 Furthermore, the polypeptide may be fused to a marker sequence, such as a peptide, which facilitates purification of the fused polypeptide. In certain embodiments of this aspect of the invention, the marker sequence is a hexa-histidine peptide, such as the tag provided in the pQE vector (Qiagen, Inc.) and the pET series of vectors (Novagen), among others, many of which are commercially available. As described in 30 Gentz et al., Proc. Nat'l. Acad. Sci., (USA) 86: 821-824 (1989), for instance, hexa-histidine provides for convenient purification of the fusion protein. The HA tag may also

be used to create fusion proteins and corresponds to an epitope derived of influenza hemagglutinin protein, which has been described by Wilson *et al.*, Cell 37: 767 (1984), for instance.

In accordance with the foregoing, the term "polynucleotide encoding a polypeptide" as used herein encompasses polynucleotides which include a sequence encoding a polypeptide of the present invention, particularly plant, and more particularly *Zea mays* phytate biosynthetic enzymes having the amino acid sequence set out below. The term encompasses polynucleotides that include a single continuous region or discontinuous regions encoding the polypeptide (for example, interrupted by integrated 10 phage or insertion sequence or editing) together with additional regions, that also may contain coding and/or non-coding sequences.

The present invention further relates to variants of the present polynucleotides which encode for fragments, analogs and derivatives of the polypeptides having the deduced amino acid sequence below. A variant of the polynucleotide may be a naturally occurring variant such as a naturally occurring allelic variant, or it may be a variant that is not known to occur naturally. Such non-naturally occurring variants of the polynucleotide may be made by mutagenesis techniques, including those applied to polynucleotides, cells or organisms.

Among variants in this regard are variants that differ from the aforementioned polynucleotides by nucleotide substitutions, deletions or additions. The substitutions may involve one or more nucleotides. The variants may be altered in coding or non-coding regions or both. Alterations in the coding regions may produce conservative or non-conservative amino acid substitutions, deletions or additions.

Among the particularly preferred embodiments of the invention in this regard are polynucleotides encoding polypeptides having the amino acid sequences set out below; variants, analogs, derivatives and fragments thereof.

Further particularly preferred in this regard are polynucleotides encoding phytate biosynthetic enzyme variants, analogs, derivatives and fragments, and variants, analogs and derivatives of the fragments, which have the amino acid sequences below 30 in which several, a few, 1 to 10, 1 to 5, 1 to 3, 2, 1 or no amino acid residues are substituted, deleted or added, in any combination. Especially preferred among these

are silent substitutions, additions and deletions, which do not alter the properties and activities of the phytate biosynthetic enzymes. Also especially preferred in this regard are conservative substitutions. Most highly preferred are polynucleotides encoding polypeptides having the amino acid sequence below, without substitutions.

5 Further preferred embodiments of the invention are polynucleotides that are greater than 79%, preferably at least 80%, more preferably at least 85% identical to a polynucleotide encoding myo-inositol 1-phosphate synthase polypeptide having the amino acid sequence set out below, and polynucleotides which are complementary to such polynucleotides. Among these particularly preferred polynucleotides, those with at
10 least 90%, 95%, 98% or at least 99% are especially preferred.

Further preferred embodiments of the invention are polynucleotides that are greater than 70%, preferably at least 75%, more preferably at least 80% identical to a polynucleotide encoding myo-inositol monophosphatase-3 polypeptide having the amino acid sequence set out below, and polynucleotides which are complementary to such polynucleotides. Among these particularly preferred polynucleotides, those with at
15 least 85%, 90%, 95%, 98% or at least 99% are especially preferred.

Further preferred embodiments of the invention are polynucleotides that are greater than 45%, preferably at least 50%, more preferably at least 55%, still more preferably at least 60% identical to a polynucleotide encoding myo-inositol 1,3,4-triphosphate 5/6-kinase polypeptide having the amino acid sequence set out below, and polynucleotides which are complementary to such polynucleotides. Among these particularly preferred polynucleotides, those with at least 65%, 70%, 75%, 80%, 85%, 90%, 95%, 98% or at least 99% are especially preferred.

Further preferred embodiments of the invention are polynucleotides that are greater than 73%, preferably at least 75%, more preferably at least 80% identical to a polynucleotide encoding phosphatidylinositol 3-kinase polypeptide having the amino acid sequence set out below, and polynucleotides which are complementary to such polynucleotides. Among these particularly preferred polynucleotides, those with at least 85%, 90%, 95%, 98% or at least 99% are especially preferred.

30 Particularly preferred embodiments in this respect, moreover, are polynucleotides which encode polypeptides which retain substantially the same or even

exhibit a reduction in the biological function or activity as the mature polypeptide encoded by the polynucleotides set out below.

The present invention further relates to polynucleotides that hybridize to the herein above-described sequences. In this regard, the present invention especially 5 relates to polynucleotides which hybridize under stringent conditions to the herein above-described polynucleotides. As herein used, the term "stringent conditions" means hybridization will occur only if there is at least 95% and preferably at least 97% identity between the sequences.

The terms "stringent conditions" or "stringent hybridization conditions" 10 includes reference to conditions under which a probe will hybridize to its target sequence, to a detectably greater degree than other sequences (e.g., at least 2-fold over background). Stringent conditions are sequence-dependent and will be different in different circumstances. By controlling the stringency of the hybridization and/or washing conditions, target sequences can be identified which are 100% 15 complementary to the probe (homologous probing). Alternatively, stringency conditions can be adjusted to allow some mismatching in sequences so that lower degrees of similarity are detected (heterologous probing). Generally, a probe is less than about 1000 nucleotides in length, preferably less than 500 nucleotides in length.

20 Typically, stringent conditions will be those in which the salt concentration is less than about 1.5 M Na ion, typically about 0.01 to 1.0 M Na ion concentration (or other salts) at pH 7.0 to 8.3 and the temperature is at least about 30°C for short probes (e.g., 10 to 50 nucleotides) and at least about 60°C for long probes (e.g., greater than 50 nucleotides). Stringent conditions may also be 25 achieved with the addition of destabilizing agents such as formamide. Exemplary low stringency conditions include hybridization with a buffer solution of 30 to 35%

formamide, 1 M NaCl, 1% SDS (sodium dodecyl sulfate) at 37°C, and a wash in 1X to 2X SSC (20X SSC = 3.0 M NaCl/0.3 M trisodium citrate) at 50 to 55°C. Exemplary moderate stringency conditions include hybridization in 40 to 45% formamide, 1 M NaCl, 1% SDS at 37°C, and a wash in 0.5X to 1X SSC at 55 to 5 60°C. Exemplary high stringency conditions include hybridization in 50% formamide, 1 M NaCl, 1% SDS at 37°C, and a wash in 0.1X SSC at 60 to 65°C.

Specificity is typically the function of post-hybridization washes, the critical factors being the ionic strength and temperature of the final wash solution. For DNA-DNA hybrids, the T_m can be approximated from the equation of Meinkoth 10 and Wahl, *Anal. Biochem.*, 138:267-284 (1984): $T_m = 81.5^{\circ}\text{C} + 16.6(\log M) + 0.41$ (%GC) - 0.61 (% form) - 500/L; where M is the molarity of monovalent cations, %GC is the percentage of guanosine and cytosine nucleotides in the DNA, % form is the percentage of formamide in the hybridization solution, and L is the length of the hybrid in base pairs. The T_m is the temperature (under defined ionic strength and 15 pH) at which 50% of a complementary target sequence hybridizes to a perfectly matched probe. T_m is reduced by about 1 °C for each 1% of mismatching; thus, T_m , hybridization and/or wash conditions can be adjusted to hybridize to sequences of the desired identity. For example, if sequences with >90% identity are sought, the T_m can be decreased 10 °C. Generally, stringent conditions are selected to be 20 about 5 °C lower than the thermal melting point (T_m) for the specific sequence and its complement at a defined ionic strength and pH. However, severely stringent conditions can utilize a hybridization and/or wash at 1, 2, 3, or 4 °C lower than the thermal melting point (T_m); moderately stringent conditions can utilize a hybridization and/or wash at 6, 7, 8, 9, or 10 °C lower than the thermal melting point (T_m); low

stringency conditions can utilize a hybridization and/or wash at 11, 12, 13, 14, 15, or 20 °C lower than the thermal melting point (T_m). Using the equation, hybridization and wash compositions, and desired T_m , those of ordinary skill will understand that variations in the stringency of hybridization and/or wash solutions are inherently described. If the desired degree of mismatching results in a T_m of less than 45 °C (aqueous solution) or 32 °C (formamide solution) it is preferred to increase the SSC concentration so that a higher temperature can be used. An extensive guide to the hybridization of nucleic acids is found in Tijssen, *Laboratory Techniques in Biochemistry and Molecular Biology—Hybridization with Nucleic Acid Probes*, Part I, 5 Chapter 2 "Overview of principles of hybridization and the strategy of nucleic acid probe assays", Elsevier, New York (1993); and *Current Protocols in Molecular Biology*, Chapter 2, Ausubel, *et al.*, Eds., Greene Publishing and Wiley-Interscience, 10 New York (1995).

As discussed additionally herein regarding polynucleotide assays of the invention, for instance, polynucleotides of the invention as discussed above, may be used as a hybridization probe for RNA, cDNA and genomic DNA to isolate full-length cDNAs and genomic clones encoding phytate biosynthetic enzymes and to isolate cDNA and genomic clones of other genes that have a high sequence similarity to the genes. Such probes generally will comprise at least 15 bases. Preferably, such probes will have at least 30 bases and may have at least 50 bases. Particularly preferred probes will have at least 30 bases and will have 50 bases or less.

The polynucleotides and polypeptides of the present invention may be employed as research reagents and materials for discovery of high phosphorous transgenic corn plants. The polynucleotides of the invention that are oligonucleotides, derived from the sequences below may be used as PCR primers in the process herein described to determine whether or not the genes identified herein in whole or in part are transcribed in phytic acid accumulating tissue.

The polynucleotides may encode a polypeptide which is the mature protein plus additional amino or carboxyl-terminal amino acids, or amino acids interior to the mature polypeptide (when the mature form has more than one polypeptide chain, for instance). Such sequences may play a role in processing of a protein from precursor to a mature 5 form, may allow protein transport, may lengthen or shorten protein half-life or may facilitate manipulation of a protein for assay or production, among other things. As generally is the case *in vivo*, the additional amino acids may be processed away from the mature protein by cellular enzymes.

A precursor protein, having the mature form of the polypeptide fused to one or 10 more prosequences may be an inactive form of the polypeptide. When prosequences are removed such inactive precursors generally are activated. Some or all of the prosequences may be removed before activation. Generally, such precursors are called proproteins.

In sum, a polynucleotide of the present invention may encode a mature protein, a 15 mature protein plus a leader sequence (which may be referred to as a preprotein), a precursor of a mature protein having one or more prosequences which are not the leader sequences of a preprotein, or a preproprotein, which is a precursor to a proprotein, having a leader sequence and one or more prosequences, which generally are removed during processing steps that produce active and mature forms of the 20 polypeptide.

Polypeptides

The present invention further relates to polypeptides that have the deduced amino acid sequences below.

25 The invention also relates to fragments, analogs and derivatives of these polypeptides. The terms "fragment," "derivative" and "analog" when referring to the polypeptides, means a polypeptide which retains essentially the same biological function or activity as such polypeptide. Fragments derivatives and analogs that retain at least 90% of the activity of the native phytate biosynthetic enzymes are preferred. 30 Fragments, derivatives and analogs that retain at least 95% of the activity of the native

polypeptides are preferred. Thus, an analog includes a proprotein which can be activated by cleavage of the proprotein portion to produce an active mature polypeptide.

The polypeptide of the present invention may be a recombinant polypeptide, a natural polypeptide or a synthetic polypeptide. In certain preferred embodiments it is a recombinant polypeptide.

The fragment, derivative or analog of the polypeptides below may be (i) one in which one or more of the amino acid residues are substituted with a conserved or non-conserved amino acid residue (preferably a conserved amino acid residue) and such substituted amino acid residue may or may not be one encoded by the genetic code, or (ii) one in which one or more of the amino acid residues includes a substituent group, or (iii) one in which the mature polypeptide is fused with another compound, such as a compound to increase the half-life of the polypeptide (for example, polyethylene glycol), or (iv) one in which the additional amino acids are fused to the mature polypeptide, such as a leader or secretory sequence or a sequence which is employed for purification of the mature polypeptide or a proprotein sequence. Such fragments, derivatives and analogs are deemed to be obtained by those of ordinary skill in the art, from the teachings herein.

Among the particularly preferred embodiments of the invention in this regard are polypeptides having the amino acid sequence of phytate biosynthetic enzymes set out below, variants, analogs, derivatives and fragments thereof, and variants, analogs and derivatives of the fragments.

Among preferred variants are those that vary from a reference by conservative amino acid substitutions. Such substitutions are those that substitute a given amino acid in a polypeptide by another amino acid of like characteristics. Typically seen as conservative substitutions are the replacements, one for another, among the aliphatic amino acids Ala, Val, Leu and Ile; interchange of the hydroxyl residues Ser and Thr, exchange of the acidic residues Asp and Glu, substitution between the amide residues Asn and Gln, exchange of the basic residues Lys and Arg and replacements among the aromatic residues Phe, Tyr.

Further particularly preferred in this regard are variants, analogs, derivatives and fragments, and variants, analogs and derivatives of the fragments, having the amino

acid sequence below, in which several, a few, 1 to 10, 1 to 5, 1 to 3, 2, 1 or no amino acid residues are substituted, deleted or added, in any combination. Especially preferred among these are silent substitutions, additions and deletions, which do not alter the properties and activities of the phytate biosynthetic enzymes. Also especially 5 preferred in this regard are conservative substitutions. Most highly preferred are polypeptides having the amino acid sequences below without substitutions.

The polypeptides and polynucleotides of the present invention are preferably provided in an isolated form, and preferably are purified to homogeneity.

The polypeptides of the present invention include the myo-inositol 1-phosphate 10 synthase polypeptide (in particular the mature polypeptide) as well as polypeptides which have greater than 88% identity (92% similarity) to the polypeptide, as described above in Needleman and Wunsch, and more preferably at least 90% identity (95% similarity), still more preferably at least 95% identity (98% similarity) and most preferably at least 98% identity and also include portions of such polypeptides with such portion of 15 the polypeptide generally containing at least 30 amino acids and more preferably at least 50 amino acids.

The polypeptides of the present invention include the myo-inositol monophosphatase-3 polypeptide (in particular the mature polypeptide) as well as polypeptides which have greater than 77% identity (82% similarity) to the polypeptide, 20 as described above in Needleman and Wunsch, more preferably at least 80% identity (85% similarity), still more preferably at least 85% identity (90% similarity), still more preferably at least 90% identity (95% similarity), still more preferably at least 95% identity (98% similarity) and most preferably at least 98% identity and also include portions of such polypeptides with such portion of the polypeptide generally containing 25 at least 30 amino acids and more preferably at least 50 amino acids.

The polypeptides of the present invention include the myo-inositol 1,3,4-triphosphate 5/6-kinase polypeptide (in particular the mature polypeptide) as well as polypeptides which have greater than 35% identity (45% similarity) to the polypeptide, as described above in Needleman and Wunsch, more preferably at least 50% identity 30 (60% similarity), still more preferably at least 60% identity (70% similarity), more preferably at least 80% identity (85% similarity), still more preferably at least 70%

identity (80% similarity), more preferably at least 80% identity (85% similarity), still more preferably at least 85% identity (90% similarity), still more preferably at least 90% identity (95% similarity), still more preferably at least 95% identity (98% similarity) and most preferably at least 98% identity and also include portions of such polypeptides with 5 such portion of the polypeptide generally containing at least 30 amino acids and more preferably at least 50 amino acids.

The polypeptides of the present invention include the phosphatidylinositol 3-kinase polypeptide (in particular the mature polypeptide) as well as polypeptides which have greater than 78% identity (84% similarity) to the polypeptide, as described above 10 in Needleman and Wunsch, more preferably at least 80% identity (85% similarity), still more preferably at least 85% identity (90% similarity), still more preferably at least 90% identity (95% similarity), still more preferably at least 95% identity (98% similarity) and most preferably at least 98% identity and also include portions of such polypeptides with such portion of the polypeptide generally containing at least 30 amino acids and more 15 preferably at least 50 amino acids.

Vectors, Host Cells, Expression

The present invention also relates to vectors comprising the polynucleotides of the present invention, host cells that incorporate the vectors of the invention and the 20 production of polypeptides of the invention by recombinant techniques.

Host cells can be genetically engineered to incorporate the polynucleotides and express polypeptides of the present invention. For instance, the polynucleotides may be introduced into host cells using well known techniques of infection, transduction, transfection, transvection and transformation. The polynucleotides may be introduced 25 alone or with other polynucleotides. Such other polynucleotides may be introduced independently, co-introduced or introduced joined to the polynucleotides of the invention.

Thus, for instance, polynucleotides of the invention may be transfected into host cells with another, separate, polynucleotide encoding a selectable marker, using 30 standard techniques for co-transfection and selection in, for instance, plant cells. In this case the polynucleotides generally will be stably incorporated into the host cell genome.

Alternatively, the polynucleotides may be joined to a vector containing a selectable marker for propagation in a host. The vector construct may also be introduced into host cells by the aforementioned techniques. Generally, a plasmid vector is introduced as DNA in a precipitate, such as a calcium phosphate precipitate, 5 or in a complex with a charged lipid. Electroporation also may be used to introduce polynucleotides into a host. If the vector is a virus, it may be packaged *in vitro* or introduced into a packaging cell and the packaged virus may be transduced into cells. A wide variety of techniques suitable for making polynucleotides and for introducing polynucleotides into cells in accordance with this aspect of the invention are well known 10 and routine to those of skill in the art. Such techniques are reviewed at length in Sambrook *et al.*, cited above, which is illustrative of the many laboratory manuals that detail these techniques.

Vectors

15 In accordance with this aspect of the invention the vector may be, for example, a plasmid vector, a single or double-stranded phage vector, a single or double-stranded RNA or DNA viral vector. Such vectors may be introduced into cells as polynucleotides, preferably DNA, by well known techniques for introducing DNA and RNA into cells. The vectors, in the case of phage and viral vectors also may be and preferably are 20 introduced into cells as packaged or encapsidated virus by well known techniques for infection and transduction. Viral vectors may be replication competent or replication defective. In the latter case viral propagation generally will occur only in complementing host cells.

Preferred among vectors, in certain respects, are those for expression of 25 polynucleotides and polypeptides of the present invention. Generally, such vectors comprise cis-acting control regions effective for expression in a host operatively linked to the polynucleotide to be expressed. Appropriate trans-acting factors either are supplied by the host, supplied by a complementing vector or supplied by the vector itself upon introduction into the host.

30 In certain preferred embodiments in this regard, the vectors provide for preferred expression. Such preferred expression may be inducible expression or expression

predominantly in certain types of cells or both inducible and cell-preferred. Particularly preferred among inducible vectors are vectors that can be induced for expression by environmental factors that are easy to manipulate, such as temperature and nutrient additives. A variety of vectors suitable to this aspect of the invention, including 5 constitutive and inducible expression vectors for use in prokaryotic and eukaryotic hosts, are well known and employed routinely by those of skill in the art. Such vectors include, among others, chromosomal, episomal and virus-derived vectors, e.g., vectors derived from bacterial plasmids, from bacteriophage, from transposons, from yeast 10 episomes, from insertion elements, from yeast chromosomal elements, from viruses such as baculoviruses, papova viruses, such as SV40, vaccinia viruses, adenoviruses, fowl pox viruses, pseudorabies viruses and retroviruses, and vectors derived from 15 combinations thereof, such as those derived from plasmid and bacteriophage genetic elements, such as cosmids and phagemids and binaries used for *Agrobacterium*-mediated transformations. All may be used for expression in accordance with this 20 aspect of the present invention. Generally, any vector suitable to maintain, propagate or express polynucleotides to express a polypeptide in a host may be used for expression in this regard.

The following vectors, which are commercially available, are provided by way of example. Among vectors preferred for use in bacteria are pQE70, pQE60 and pQE-9, 20 available from Qiagen; pBS vectors, Phagescript vectors, Bluescript vectors, pNH8A, pNH16a, pNH18A, pNH46A, available from Stratagene; and ptrc99a, pKK223-3, pKK233-3, pDR540, pRIT5 available from Pharmacia. Among preferred eukaryotic 25 vectors are pWLNEO, pSV2CAT, pOG44, pXT1 and pSG available from Stratagene; and pSVK3, pBPV, pMSG and pSVL available from Pharmacia. Useful plant binaries vectors include BIN19 and its derivatives available from Clontech. These vectors are listed solely by way of illustration of the many commercially available and well known 30 vectors that are available to those of skill in the art for use in accordance with this aspect of the present invention. It will be appreciated that any other plasmid or vector suitable for, for example, introduction, maintenance, propagation or expression of a polynucleotide or polypeptide of the invention in a host may be used in this aspect of the invention.

In general, expression constructs will contain sites for transcription initiation and termination, and, in the transcribed region, a ribosome binding site for translation. The coding portion of the mature transcripts expressed by the constructs will include a translation initiating AUG at the beginning and a termination codon appropriately positioned at the end of the polypeptide to be translated.

In addition, the constructs may contain control regions that regulate as well as engender expression. Generally, in accordance with many commonly practiced procedures, such regions will operate by controlling transcription, such as transcription factors, repressor binding sites and termination, among others. For secretion of the translated protein into the lumen of the endoplasmic reticulum, into the periplasmic space or into the extracellular environment, appropriate secretion signals may be incorporated into the expressed polypeptide. These signals may be endogenous to the polypeptide or they may be heterologous signals.

Generally, recombinant expression vectors will include origins of replication, a promoter derived from a highly-expressed gene to direct transcription of a downstream structural sequence, and a selectable marker to permit isolation of vector containing cells after exposure to the vector.

Transcription of the DNA encoding the polypeptides of the present invention by higher eukaryotes may be increased by inserting an enhancer sequence into the vector. Enhancers are cis-acting elements of DNA, usually about from 10 to 300 bp that act to increase transcriptional activity of a promoter in a given host cell-type. Examples of enhancers include the SV40 enhancer, which is located on the late side of the replication origin at bp 100 to 270, the cytomegalovirus early promoter enhancer, the polyoma enhancer on the late side of the replication origin, and adenovirus enhancers. Additional enhancers useful in the invention to increase transcription of the introduced DNA segment, include, *inter alia*, viral enhancers like those within the 35S promoter, as shown by Odell *et al.*, Plant Mol. Biol. 10: 263-72 (1988), and an enhancer from an opine gene as described by Fromm *et al.*, Plant Cell 1: 977 (1989).

Among known eukaryotic promoters suitable in this regard are the CMV immediate early promoter, the HSV thymidine kinase promoter, the early and late SV40 promoters, the promoters of retroviral LTRs, such as those of the Rous sarcoma virus

("RSV"), metallothionein promoters, such as the mouse metallothionein-I promoter and various plant promoters, such as globulin-1. When available, the native promoters of the phytate biosynthetic enzyme genes may be used.

As mentioned above, the DNA sequence in the expression vector is operatively linked to appropriate expression control sequence(s), including, for instance, a promoter to direct mRNA transcription. Representatives of prokaryotic promoters include the phage lambda PL promoter, the *E. coli* lac, trp and tac promoters to name just a few of the well-known promoters.

With respect to plants, examples of seed-specific promoters include promoters of seed storage proteins which express these proteins in seeds in a highly regulated manner (Thompson, et al.; *BioEssays*; 10: 108; (1989), incorporated herein in its entirety by reference), such as, for dicotyledonous plants, a bean β -phaseolin promoter, a napin promoter, a β -conglycinin promoter, and a soybean lectin promoter. For monocotyledonous plants, promoters useful in the practice of the invention include, but are not limited to, a maize 15 kD zein promoter, a 22 kD zein promoter, a γ -zein promoter, a waxy promoter, a shrunken 1 promoter, a globulin 1 promoter, and the shrunken 2 promoter. However, other promoters useful in the practice of the invention are known to those of skill in the art.

Other examples of suitable promoters are the promoter for the small subunit of ribulose-1,5-bis-phosphate carboxylase, promoters from tumor-inducing plasmids of *Agrobacterium tumefaciens*, such as the nopaline synthase and octopine synthase promoters, and viral promoters such as the cauliflower mosaic virus (CaMV) 19S and 35S promoters or the figwort mosaic virus 35S promoter.

It will be understood that numerous promoters not mentioned are suitable for use in this aspect of the invention are well known and readily may be employed by those of skill in the manner illustrated by the discussion and the examples herein. For example this invention contemplates using the native phytate biosynthetic enzyme promoters to drive the expression of the enzyme in a recombinant environment.

Vectors for propagation and expression generally will include selectable markers. Such markers also may be suitable for amplification or the vectors may

contain additional markers for this purpose. In this regard, the expression vectors preferably contain one or more selectable marker genes to provide a phenotypic trait for selection of transformed host cells. Preferred markers include dihydrofolate reductase or neomycin resistance for eukaryotic cell culture, and tetracycline or ampicillin 5 resistance genes for culturing *E. coli* and other prokaryotes. Kanamycin and herbicide resistance genes (PAT and BAR) are generally useful in plant systems.

Selectable marker genes, in physical proximity to the introduced DNA segment, are used to allow transformed cells to be recovered by either positive genetic selection or screening. The selectable marker genes also allow for maintaining selection 10 pressure on a transgenic plant population, to ensure that the introduced DNA segment, and its controlling promoters and enhancers, are retained by the transgenic plant.

Many of the commonly used positive selectable marker genes for plant transformation have been isolated from bacteria and code for enzymes that metabolically detoxify a selective chemical agent which may be an antibiotic or a 15 herbicide. Other positive selection marker genes encode an altered target which is insensitive to the inhibitor.

A preferred selection marker gene for plant transformation is the BAR or PAT gene, which is used with the selecting agent bialaphos. Spencer *et al.*, T. Thero. Appl'd Genetics 79, 625-631, (1990). Another useful selection marker gene is the neomycin 20 phosphotransferase II (*nptII*) gene, isolated from Tn5, which confers resistance to kanamycin when placed under the control of plant regulatory signals. Fraley *et al.*, Proc. Nat'l Acad. Sci. (USA) 80: 4803 (1983). The hygromycin phosphotransferase gene, which confers resistance to the antibiotic hygromycin, is a further example of a useful selectable marker. Vanden Elzen *et al.*, Plant Mol. Biol. 5: 299 (1985). 25 Additional positive selectable markers genes of bacterial origin that confer resistance to antibiotics include gentamicin acetyl transferase, streptomycin phosphotransferase, aminoglycoside-3'-adenyl transferase and the bleomycin resistance determinant. Hayford *et al.*, Plant Physiol. 86: 1216 (1988); Jones *et al.*, Mol. Gen. Genet. 210: 86 (1987); Svab *et al.*, Plant Mol. Biol. 14: 197 (1990); Hille *et al.*, Plant Mol. Biol. 7: 171 30 (1986).

Other positive selectable marker genes for plant transformation are not of bacterial origin. These genes include mouse dihydrofolate reductase, plant 5-enolpyruvylshikimate-3-phosphate synthase and plant acetolactate synthase. Eichholtz *et al.*, Somatic Cell Mol. Genet. 13: 67 (1987); Shah *et al.*, Science 233: 478 5 (1986); Charest *et al.*, Plant Cell Rep. 8: 643 (1990).

Another class of useful marker genes for plant transformation with the DNA sequence requires screening of presumptively transformed plant cells rather than direct genetic selection of transformed cells for resistance to a toxic substance such as an antibiotic. These genes are particularly useful to quantitate or visualize the spatial 10 pattern of expression of the DNA sequence in specific tissues and are frequently referred to as reporter genes because they can be fused to a gene or gene regulatory sequence for the investigation of gene expression. Commonly used genes for screening presumptively transformed cells include β -glucuronidase (GUS), β -galactosidase, luciferase, and chloramphenicol acetyltransferase. Jefferson, Plant Mol. Biol. Rep. 5: 387 (1987); Teeri *et al.*, EMBO J. 8: 343 (1989); Koncz *et al.*, Proc. Nat'l Acad. Sci. (USA) 84: 131 (1987); De Block *et al.*, EMBO J. 3: 1681 (1984). Another 15 approach to the identification of relatively rare transformation events has been use of a gene that encodes a dominant constitutive regulator of the *Zea mays* anthocyanin pigmentation pathway (Ludwig *et al.*, Science 247: 449 (1990)).

20 The appropriate DNA sequence may be inserted into the vector by any of a variety of well-known and routine techniques. In general, a DNA sequence for expression is joined to an expression vector by cleaving the DNA sequence and the expression vector with one or more restriction endonucleases and then joining the restriction fragments together using T4 DNA ligase. The sequence may be inserted in a 25 forward or reverse orientation. Procedures for restriction and ligation that can be used to this end are well known and routine to those of skill. Suitable procedures in this regard, and for constructing expression vectors using alternative techniques, which also are well known and routine to those skill, are set forth in great detail in Sambrook *et al.*, MOLECULAR CLONING, A LABORATORY MANUAL, 2nd Ed.; Cold Spring Harbor 30 Laboratory Press, Cold Spring Harbor, New York (1989).

Polynucleotides of the invention, encoding the heterologous structural sequence of a polypeptide of the invention generally will be inserted into the vector using standard techniques so that it is operably linked to the promoter for expression. The polynucleotide will be positioned so that the transcription start site is located 5 appropriately 5' to a ribosome binding site. The ribosome binding site will be 5' to the AUG that initiates translation of the polypeptide to be expressed. Generally, there will be no other open reading frames that begin with an initiation codon, usually AUG, and lie between the ribosome binding site and the initiation codon. Also, generally, there will be a translation stop codon at the end of the polypeptide and there will be a 10 polyadenylation signal in constructs for use in eukaryotic hosts. Transcription termination signal appropriately disposed at the 3' end of the transcribed region may also be included in the polynucleotide construct.

The vector containing the appropriate DNA sequence as described elsewhere herein, as well as an appropriate promoter, and other appropriate control sequences, 15 may be introduced into an appropriate host using a variety of well known techniques suitable to expression therein of a desired polypeptide. The present invention also relates to host cells containing the above-described constructs discussed. The host cell can be a higher eukaryotic cell, such as a mammalian or plant cell, or a lower eukaryotic cell, such as a yeast cell, or the host cell can be a prokaryotic cell, such as a bacterial 20 cell.

Introduction of the construct into the host cell can be effected by calcium phosphate transfection, DEAE-dextran mediated transfection, microinjection, cationic lipid-mediated transfection, electroporation, transduction, scrape loading, ballistic introduction, infection or other methods. Such methods are described in many standard 25 laboratory manuals, such as Davis *et al.*, *BASIC METHODS IN MOLECULAR BIOLOGY*, (1986) and Sambrook *et al.*, *MOLECULAR CLONING: A LABORATORY MANUAL*, 2nd Ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989).

Representative examples of appropriate hosts include bacterial cells, such as 30 streptococci, staphylococci, *E. coli*, streptomycetes and *Salmonella typhimurium* cells; fungal cells, such as yeast cells and *Aspergillus* cells; insect cells such as *Drosophila*

S2 and *Spodoptera* Sf9 cells; animal cells such as CHO, COS and Bowes melanoma cells; and plant cells. Hosts for a great variety of expression constructs are well known, and those of skill will be enabled by the present disclosure readily to select a host for expressing a polypeptide in accordance with this aspect of the present invention.

5 The engineered host cells can be cultured in conventional nutrient media, which may be modified as appropriate for, *inter alia*, activating promoters, selecting transformants or amplifying genes. Culture conditions, such as temperature, pH and the like, previously used with the host cell selected for expression generally will be suitable for expression of polypeptides of the present invention as will be apparent to
10 those of skill in the art.

Constructs in host cells can be used in a conventional manner to produce the gene product encoded by the recombinant sequence. Alternatively, the polypeptides of the invention can be synthetically produced by conventional peptide synthesizers.

15 Mature proteins can be expressed in mammalian cells, yeast, bacteria, or other cells under the control of appropriate promoters. Cell-free translation systems can also be employed to produce such proteins using RNAs derived from the DNA constructs of the present invention.

20 Following transformation of a suitable host strain and growth of the host strain to an appropriate cell density, where the selected promoter is inducible it is induced by appropriate means (e.g., temperature shift or exposure to chemical inducer) and cells are cultured for an additional period.

25 Cells typically then are harvested by centrifugation, disrupted by physical or chemical means, and the resulting crude extract retained for further purification. Microbial cells employed in expression of proteins can be disrupted by any convenient method, including freeze-thaw cycling, sonication, mechanical disruption, or use of cell lysing agents, such methods are well known to those skilled in the art.

30 As noted above, the present invention provides vectors capable of expressing phytate biosynthetic enzymes under the control of suitable promoters. In general, the vectors should be functional in plant cells. At times, it may be preferable to have vectors that are functional in *E. coli* (e.g., production of protein for raising antibodies, DNA sequence analysis, construction of inserts, obtaining

quantities of nucleic acids and proteins). Vectors and procedures for cloning and expression in *E. coli* are discussed above and, for example, in Sambrook *et al.* (*supra*) and in Ausubel *et al.* (*supra*).

Vectors that are functional in plants are preferably binary plasmids derived from *Agrobacterium* plasmids. Such vectors are capable of transforming plant cells. These vectors contain left and right border sequences that are required for integration into the host (plant) chromosome. At minimum, between these border sequences is the gene to be expressed under control of a promoter. In preferred embodiments, a selectable marker and a reporter gene are also included. For ease of obtaining sufficient quantities of vector, a bacterial origin that allows replication in *E. coli* is preferred.

In certain preferred embodiments, the vector contains a reporter gene and the structural genes of this invention. The reporter gene should allow ready determination of transformation and expression. The GUS (β -glucuronidase) gene is preferred (U.S. Patent No. 5,268,463). Other reporter genes, such as β -galactosidase, luciferase, GFP, and the like, are also suitable in the context of this invention. Methods and substrates for assaying expression of each of these genes are well known in the art. The reporter gene should be under control of a promoter that is functional in plants. Such promoters include CaMV 35S promoter, mannopine synthase promoter, ubiquitin promoter and DNA J promoter.

Preferably, the vector contains a selectable marker for identifying transformants. The selectable marker may confer a growth advantage under appropriate conditions. Generally, selectable markers are drug resistance genes, such as neomycin phosphotransferase. Other drug resistance genes are known to those in the art and may be readily substituted. The selectable marker has a linked constitutive or inducible promoter and a termination sequence, including a polyadenylation signal sequence.

Additionally, a bacterial origin of replication and a selectable marker for bacteria are preferably included in the vector. Of the various origins (e.g., colEI, fd phage), a colEI origin of replication is preferred. Most preferred is the origin from the pUC plasmids, which allow high copy number.

A general vector suitable for use in the present invention is based on pBI121 (U.S. Patent No. 5,432,081) a derivative of pBIN19. Other vectors have been described (U.S. Patent No. 4,536,475) or may be constructed based on the guidelines presented herein. The plasmid pBI121 contains a left and right border sequence for integration into a plant host chromosome. These border sequences flank two genes. One is a kanamycin resistance gene (neomycin phosphotransferase) driven by a nopaline synthase promoter and using a nopaline synthase polyadenylation site. The second is the *E. coli* GUS gene under control of the CaMV 35S promoter and polyadenylated using a nopaline synthase polyadenylation site. Plasmid pBI121 also contains a bacterial origin of replication and selectable marker.

In certain embodiments, the vector may contain the structural genes identified herein under control of a promoter. The promoter may be the native promoters associated with the structural genes themselves or a strong, constitutive promoter, such as CaMV 35S promoter. Other elements that are preferred for optimal expression (e.g., transcription termination site, enhancer, splice site) may also be included. The genes may alternatively be expressed as fusion proteins with a reporter gene, for example.

20 Plant Transformation Methods

As discussed above the present invention also provides methods for producing a plant which expresses a foreign gene, comprising the steps of (a) introducing a vector as described above into an embryogenic plant cell, wherein the vector contains a foreign gene in an expressible form, and (b) producing a plant 25 from the embryogenic plant cell, wherein the plant expresses the foreign gene.

Vectors may be introduced into plant cells by any of several methods. For example, DNA may be introduced as a plasmid by *Agrobacterium* in co-cultivation or bombardment. Other transformation methods include electroporation, CaPO₄-mediated transfection, and the like. Preferably, DNA is first transfected into 30 *Agrobacterium* and subsequently introduced into plant cells. Most preferably, the

infection is achieved by co-cultivation. In part, the choice of transformation methods depends upon the plant to be transformed.

Phytate biosynthetic polypeptides can be recovered and purified from recombinant cell cultures by well-known methods including ammonium sulfate or 5 ethanol precipitation, acid extraction, anion or cation exchange chromatography, phosphocellulose chromatography, hydrophobic interaction chromatography, affinity chromatography, hydroxylapatite chromatography and lectin chromatography. Most preferably, high performance liquid chromatography ("HPLC") is employed for purification. Well known techniques for refolding protein may be employed to 10 regenerate active conformation when the polypeptide is denatured during isolation and or purification.

Polypeptides of the present invention include naturally purified products, products of chemical synthetic procedures, and products produced by recombinant 15 techniques from a prokaryotic or eukaryotic host, including, for example, bacterial, yeast, higher plant, insect and mammalian cells. Depending upon the host employed in a recombinant production procedure, the polypeptides of the present invention may be glycosylated or may be non-glycosylated. In addition, polypeptides of the invention may also include an initial modified methionine residue, in some cases as a result of host-mediated processes.

20 It is appreciated that the gene expressing the polypeptide of interest may have to be "codon-optimized" to affect efficient expression of a particular host. Thus, this invention contemplates selecting from the sequences below, the particular codon optimized sequence for the particular host cell of interest.

Other genes of interest may be "stacked" during the same transformation events. 25 For example, other genes of interest may impart disease, pest or herbicide resistance, or improve the feed and food quality of the plant or seed, such increased or altered oil expression or altered protein or carbohydrate expression.

Regeneration of Transformed Plants

30 Following transformation, regeneration is involved to obtain a whole plant from transformed cells. Techniques for regenerating plants from tissue culture such as

transformed protoplasts or callus cell lines, are known in the art. For example, see Phillips, et al.; Plant Cell Tissue Organ Culture; Vol. 1: p 123; (1981); Patterson, et al.; Plant Sci.; Vol. 42; p. 125; (1985); Wright, et al.; Plant Cell Reports; Vol. 6: p. 83; (1987); and Barwale, et al.; Planta; Vol. 167; p. 473 (1986); each incorporated herein in its entirety by reference.

5 The selection of an appropriate method is within the skill of the art.

It is expected that the transformed plants will be used in traditional breeding programs, including TOPCROSS pollination systems as disclosed in US 5,706,603 and US 5,704,160 the disclosure of each is incorporated herein by reference.

10 **Polynucleotide Assays**

This invention is also related to the use of the phytate biosynthetic enzyme polynucleotides in marker to assist in breeding program, as described for example in PCT publication US89/00709. The DNA may be used directly for detection or may be amplified enzymatically by using PCR prior to analysis. PCR (Saiki et al., Nature 324: 15 163-166 (1986)). RNA or cDNA may also be used in the same ways. As an example, PCR primers complementary to the nucleic acid encoding the phytate biosynthetic enzymes can be used to identify and analyze phytate biosynthetic enzyme presence and expression. Using PCR, characterization of the gene present in a particular tissue or plant variety may be made by an analysis of the genotype of the tissue or variety. 20 For example, deletions and insertions can be detected by a change in size of the amplified product in comparison to the genotype of a reference sequence. Point mutations can be identified by hybridizing amplified DNA to radiolabeled phytate biosynthetic enzyme RNA or alternatively, radiolabeled phytate biosynthetic enzyme antisense DNA sequences. Perfectly matched sequences can be distinguished from 25 mismatched duplexes by RNase A digestion or by differences in melting temperatures.

Sequence differences between a reference gene and genes having mutations also may be revealed by direct DNA sequencing. In addition, cloned DNA segments may be employed as probes to detect specific DNA segments. The sensitivity of such methods can be greatly enhanced by appropriate use of PCR or another amplification 30 method. For example, a sequencing primer is used with double-stranded PCR product or a single-stranded template molecule generated by a modified PCR. The sequence

determination is performed by conventional procedures with radiolabeled nucleotide or by automatic sequencing procedures with fluorescent-tags.

Genetic typing of various varieties of plants based on DNA sequence differences may be achieved by detection of alteration in electrophoretic mobility of DNA fragments 5 in gels, with or without denaturing agents. Small sequence deletions and insertions can be visualized by high resolution gel electrophoresis. DNA fragments of different sequences may be distinguished on denaturing formamide gradient gels in which the mobilities of different DNA fragments are retarded in the gel at different positions according to their specific melting or partial melting temperatures (see, e.g., Myers et 10 al., Science, 230: 1242 (1985)).

Sequence changes at specific locations also may be revealed by nuclease protection assays, such as RNase and S1 protection or the chemical cleavage method (e.g., Cotton et al., Proc. Nat'l. Acad. Sci., (USA), 85: 4397-4401 (1985)).

Thus, the detection of a specific DNA sequence may be achieved by methods 15 such as hybridization, RNase protection, chemical cleavage, direct DNA sequencing or the use of restriction enzymes, (e.g., restriction fragment length polymorphisms ("RFLP") and Southern blotting of genomic DNA.

In addition to more conventional gel-electrophoresis and DNA sequencing, mutations also can be detected by *in situ* analysis.

20 A mutation may be ascertained for example, by a DNA sequencing assay. Samples are processed by methods known in the art to capture the RNA. First strand cDNA is synthesized from the RNA samples by adding an oligonucleotide primer consisting of sequences which hybridize to a region on the mRNA. Reverse transcriptase and deoxynucleotides are added to allow synthesis of the first strand 25 cDNA. Primer sequences are synthesized based on the DNA sequences of the phytate biosynthetic enzymes of the invention. The primer sequence is generally comprised of at least 15 consecutive bases, and may contain at least 30 or even 50 consecutive bases.

Cells carrying mutations or polymorphisms in the gene of the present invention 30 may also be detected at the DNA level by a variety of techniques. The DNA may be used directly for detection or may be amplified enzymatically by using PCR (Saiki et al.,

Nature, 324:163-166 (1986)) prior to analysis. RT-PCR can also be used to detect mutations. It is particularly preferred to used RT-PCR in conjunction with automated detection systems, such as, for example, GeneScan. RNA or cDNA may also be used for the same purpose, PCR or RT-PCR. As an example, PCR primers complementary 5 to the nucleic acid encoding phytate biosynthetic enzymes can be used to identify and analyze mutations. Examples of representative primers are shown below in Table 1. For example, deletions and insertions can be detected by a change in size of the amplified product in comparison to the normal genotype. Point mutations can be identified by hybridizing amplified DNA to radiolabeled RNA or alternatively, 10 radiolabeled antisense DNA sequences. While perfectly matched sequences can be distinguished from mismatched duplexes by RNase A digestion or by differences in melting temperatures, preferably point mutations are identified by sequence analysis.

15 Primers used for detection of mutations or polymorphisms in myo-inositol 1-phosphate synthase gene

5'CTCGCTACCTCGCTCGCATTCCATT 3'

5'ACGCCACTTGGCTCACTTGTACTCCA 3'

20 Primers used for detection of mutations or polymorphisms in myo-inositol monophosphatase-3 gene

5'ACGAGGTTGCAGGCGAACCGAAAAT 3'

5'TAGGGACCGTTGCCTAACCTAT 3'

25 Primers used for detection of mutations or polymorphisms in myo-inositol 1,3,4-trisphosphate 5/6-kinase gene

5'TTCTCTCGGTCGCCGCTACTGG 3'

5'AGCATAACAGTTAGCACCT 3'

30 Primers used for detection of mutations or polymorphisms in phosphatidylinositol 3-kinase gene

5' CCGCTTCTCC TCACCTTCCT CT 3'

5' TGGCTTGTGA CAGTCAGCAT GT 3'

The above primers may be used for amplifying phytate biosynthetic enzyme cDNA or genomic clones isolated from a sample derived from an individual plant. The invention also provides the primers above with 1, 2, 3 or 4 nucleotides removed from 5 the 5' and/or the 3' end. The primers may be used to amplify the gene isolated from the individual such that the gene may then be subject to various techniques for elucidation of the DNA sequence. In this way, mutations in the DNA sequence may be identified.

Polypeptide Assays

10 The present invention also relates to diagnostic assays such as quantitative and diagnostic assays for detecting levels of phytate biosynthetic enzymes in cells and tissues, including determination of normal and abnormal levels. Thus, for instance, a diagnostic assay in accordance with the invention for detecting expression of phytate biosynthetic enzymes compared to normal control tissue samples may be used to detect 15 unacceptable levels of expression. Assay techniques that can be used to determine levels of polypeptides of the present invention, in a sample derived from a plant source are well-known to those of skill in the art. Such assay methods include radioimmunoassays, competitive-binding assays, Western Blot analysis and ELISA assays. Among these ELISAs frequently are preferred. An ELISA assay initially 20 comprises preparing an antibody specific to the polypeptide, preferably a monoclonal antibody. In addition a reporter antibody generally is prepared which binds to the monoclonal antibody. The reporter antibody is attached to a detectable reagent such as radioactive, fluorescent or enzymatic reagent, in this example horseradish peroxidase enzyme.

25 To carry out an ELISA a sample is removed from a host and incubated on a solid support, e.g., a polystyrene dish, that binds the proteins in the sample. Any free protein binding sites on the dish are then covered by incubating with a non-specific protein such as bovine serum albumin. Next, the monoclonal antibody is incubated in the dish during which time the monoclonal antibodies attach to any phytate biosynthetic 30 enzymes attached to the polystyrene dish. Unbound monoclonal antibody is washed out with buffer. The reporter antibody linked to horseradish peroxidase is placed in the

dish resulting in binding of the reporter antibody to any monoclonal antibody bound to phytate biosynthetic enzyme. Unattached reporter antibody is then washed out. Reagents for peroxidase activity, including a colorimetric substrate are then added to the dish. Immobilized peroxidase, linked to phytate biosynthetic enzyme through the 5 primary and secondary antibodies, produces a colored reaction product. The amount of color developed in a given time period indicates the amount of phytate biosynthetic enzyme present in the sample. Quantitative results typically are obtained by reference to a standard curve.

A competition assay may be employed wherein antibodies specific to phytate 10 biosynthetic enzymes attached to a solid support and labeled enzyme derived from the host are passed over the solid support and the amount of label detected attached to the solid support can be correlated to a quantity of phytate biosynthetic enzyme in the sample.

15 **Antibodies**

The polypeptides, their fragments or other derivatives, or analogs thereof, or 20 cells expressing them can be used as immunogens to produce antibodies thereto. These antibodies can be, for example, polyclonal or monoclonal antibodies. The present invention also includes chimeric, single chain, and humanized antibodies, as well as Fab fragments, or the product of an Fab expression library. Various procedures known in the art may be used for the production of such antibodies and fragments.

Antibodies generated against the polypeptides corresponding to a sequence of 25 the present invention can be obtained by direct injection of the polypeptides into an animal or by administering the polypeptides to an animal, preferably a nonhuman. The antibody so obtained will then bind the polypeptides itself. In this manner, even a sequence encoding only a fragment of the polypeptide can be used to generate antibodies binding the whole native polypeptide. Such antibodies can then be used to isolate the polypeptide from tissue expressing that polypeptide.

For preparation of monoclonal antibodies, any technique which provides 30 antibodies produced by continuous cell line cultures can be used. Examples include the hybridoma technique (Kohler, G. and Milstein, C., Nature 256: 495-497 (1975)), the

trioma technique, the human B-cell hybridoma technique (Kozbor *et al.*, Immunology Today 4: 72 (1983)) and the EBV-hybridoma technique to produce human monoclonal antibodies (Cole *et al.*, pg. 77-96 in *MONOCLONAL ANTIBODIES AND CANCER THERAPY*, Alan R. Liss, Inc. (1985)).

5 Hybridoma cell lines secreting the monoclonal antibody are another aspect of this invention.

Techniques described for the production of single chain antibodies (U.S. Patent N 4,946,778) can be adapted to produce single chain antibodies to immunogenic polypeptide products of this invention. Also, transgenic mice, or other organisms such 10 as other mammals, may be used to express humanized antibodies to immunogenic polypeptide products of this invention.

The above-described antibodies may be employed to isolate or to identify clones expressing the polypeptide or purify the polypeptide of the present invention by attachment of the antibody to a solid support for isolation and/or purification by affinity 15 chromatography.

Polypeptide derivatives include antigenically or immunologically equivalent derivatives which form a particular aspect of this invention.

The term 'antigenically equivalent derivative' as used herein encompasses a polypeptide or its equivalent which will be specifically recognized by certain 20 antibodies which, when raised to the protein or polypeptide according to the present invention, interfere with the immediate physical interaction between the antibody and its cognate antigen.

The term "immunologically equivalent derivative" as used herein encompasses a peptide or its equivalent which when used in a suitable formulation 25 to raise antibodies in a vertebrate, the antibodies act to interfere with the immediate physical interaction between the antibody and its cognate antigen

The polypeptide, such as an antigenically or immunologically equivalent derivative or a fusion protein thereof is used as an antigen to immunize a mouse or other animal such as a rat guinea pig, goat, rabbit, sheep, cattle or chicken. The 30 fusion protein may provide stability to the polypeptide. The antigen may be associated, for example by conjugation, with an immunogenic carrier protein for

example bovine serum albumin (BSA) or keyhole limpet haemocyanin (KLH). Alternatively a multiple antigenic peptide comprising multiple copies of the protein or polypeptide, or an antigenically or immunologically equivalent polypeptide thereof may be sufficiently antigenic to improve immunogenicity so as to obviate the use of 5 a carrier.

Alternatively phage display technology could be utilized to select antibody genes with binding activities towards the polypeptide either from repertoires of PCR amplified v-genes of lymphocytes from humans screened for possessing anti-Fbp or from naive libraries (McCafferty, J. et al., (1990), Nature 348: 552-554; Marks, J. et 10 al., (1992) Biotechnology 10: 779-783). The affinity of these antibodies can also be improved by chain shuffling (Clackson, T. et al., (1991) Nature 352: 624-628).

The antibody should be screened again for high affinity to the polypeptide and/or fusion protein.

As mentioned above, a fragment of the final antibody may be prepared.

15 The antibody may be either intact antibody of M_r approximately 150,000 or a derivative of it, for example a Fab fragment or a Fv fragment as described in Sierra, A and Pluckthun, A., Science 240: 1038-1040 (1988). If two antigen binding domains are present each domain may be directed against a different epitope - termed 'bispecific' antibodies.

20 The antibody of the invention, as mentioned above, may be prepared by conventional means for example by established monoclonal antibody technology (Kohler, G. and Milstein, C., Nature, 256: 495-497 (1975)) or using recombinant means e.g. combinatorial libraries, for example as described in Huse, W.D. et al., Science 246: 1275-1281 (1989).

25 Preferably the antibody is prepared by expression of a DNA polymer encoding said antibody in an appropriate expression system such as described above for the expression of polypeptides of the invention. The choice of vector for the expression system will be determined in part by the host, which may be a prokaryotic cell, such as *E. coli* (preferably strain B) or *Streptomyces* sp. or a 30 eukaryotic cell, such as a mouse C127, mouse myeloma, human HeLa, Chinese hamster ovary, filamentous or unicellular fungi or insect cell. The host may also be

a transgenic animal or a transgenic plant for example as described in Hiatt, A. *et al.*, Nature 340: 76-78 (1989). Suitable vectors include plasmids, bacteriophages, cosmids and recombinant viruses, derived from, for example, baculoviruses and vaccinia.

5 The Fab fragment may also be prepared from its parent monoclonal antibody by enzyme treatment, for example using papain to cleave the Fab portion from the Fc portion.

Phytate Biosynthetic Enzyme Binding Molecules and Assays

10 This invention also provides a method for identification of molecules, such as binding molecules, that bind the phytate biosynthetic enzymes. Genes encoding proteins that bind the enzymes, such as binding proteins, can be identified by numerous methods known to those of skill in the art, for example, ligand panning and FACS sorting. Such methods are described in many laboratory manuals such as, for instance,

15 Coligan *et al.*, *Current Protocols in Immunology* 1(2): Chapter 5 (1991).

For instance, expression cloning may be employed for this purpose. To this end polyadenylated RNA is prepared from a cell expressing the phytate biosynthetic enzymes, a cDNA library is created from this RNA, the library is divided into pools and the pools are transfected individually into cells that are not expressing the enzyme. The 20 transfected cells then are exposed to labeled enzyme. The enzyme can be labeled by a variety of well-known techniques including standard methods of radio-iodination or inclusion of a recognition site for a site-specific protein kinase. Following exposure, the cells are fixed and binding of enzyme is determined. These procedures conveniently are carried out on glass slides.

25 Pools are identified of cDNA that produced phytate biosynthetic enzyme-binding cells. Sub-pools are prepared from these positives, transfected into host cells and screened as described above. Using an iterative sub-pooling and re-screening process, one or more single clones that encode the putative binding molecule can be isolated.

30 Alternatively a labeled ligand can be photoaffinity linked to a cell extract, such as a membrane or a membrane extract, prepared from cells that express a molecule that it binds, such as a binding molecule. Cross-linked material is resolved by polyacrylamide

gel electrophoresis ("PAGE") and exposed to X-ray film. The labeled complex containing the ligand-binding can be excised, resolved into peptide fragments, and subjected to protein microsequencing. The amino acid sequence obtained from microsequencing can be used to design unique or degenerate oligonucleotide probes to 5 screen cDNA libraries to identify genes encoding the putative binding molecule.

Polypeptides of the invention also can be used to assess phytate biosynthetic enzyme binding capacity of phytate biosynthetic enzyme binding molecules, such as binding molecules, in cells or in cell-free preparations.

Polypeptides of the invention may also be used to assess the binding of small 10 molecule substrates and ligands in, for example, cells, cell-free preparations, chemical libraries, and natural product mixtures. These substrates and ligands may be natural substrates and ligands or may be structural or functional mimetics.

Anti-phytate biosynthetic enzyme antibodies represent a useful class of binding molecules contemplated by this invention.

15

Antagonists - Assays and Molecules

The invention also provides a method of screening compounds to identify those which enhance or block the action of phytate biosynthetic enzymes on cells, such as its interaction with substrate molecules. An antagonist is a compound which decreases the 20 natural biological functions of the enzymes.

Potential antagonists include small organic molecules, peptides, polypeptides and antibodies that bind to a polypeptide of the invention and thereby inhibit or extinguish its activity. Potential antagonists also may be small organic molecules, a peptide, a polypeptide such as a closely related protein or antibody that binds the same 25 sites on a binding molecule, such as a binding molecule, without inducing phytate biosynthetic enzyme-induced activities, thereby preventing the action of the enzyme by excluding the enzyme from binding.

Potential antagonists include a small molecule which binds to and occupies the binding site of the polypeptide thereby preventing binding to cellular binding molecules, 30 such as binding molecules, such that normal biological activity is prevented. Examples

of small molecules include but are not limited to small organic molecules, peptides or peptide-like molecules.

Other potential antagonists include molecules that affect the expression of the gene encoding phytate biosynthetic enzymes (e.g. transactivation inhibitors). Other 5 potential antagonists include antisense molecules. Antisense technology can be used to control gene expression through antisense DNA or RNA or through double- or triple-helix formation. Antisense techniques are discussed, for example, in - Okano, J. Neurochem. 56: 560 (1991); *OLIGODEOXYNUCLEOTIDES AS ANTISENSE INHIBITORS OF GENE EXPRESSION*, CRC Press, Boca Raton, FL (1988). Triple 10 helix formation is discussed in, for instance Lee et al., *Nucleic Acids Research* 6: 3073 (1979); Cooney et al., *Science* 241: 456 (1988); and Dervan et al., *Science* 251: 1360 (1991). The methods are based on binding of a polynucleotide to a complementary 15 DNA or RNA. For example, the 5' coding portion of a polynucleotide that encodes the mature polypeptide of the present invention may be used to design an antisense RNA oligonucleotide of from about 10 to 40 base pairs in length. A DNA oligonucleotide is 20 designed to be complementary to a region of the gene involved in transcription thereby preventing transcription and the production of phytate biosynthetic enzymes. The antisense RNA oligonucleotide hybridizes to the mRNA in vivo and blocks translation of the mRNA molecule into phytate biosynthetic enzymes. The oligonucleotides described above can also be delivered to cells such that the antisense RNA or DNA may be expressed in vivo to inhibit production of phytate biosynthetic enzymes.

The antagonists may be employed for instance to reduce the levels of phytate and/or increase the available phosphorous in plant cells.

25

Examples

The present invention is further described by the following examples. The examples are provided solely to illustrate the invention by reference to specific embodiments. These exemplifications, while illustrating certain specific aspects of the 30 invention, do not portray the limitations or circumscribe the scope of the disclosed invention.

Certain terms used herein are explained in the foregoing glossary.

All examples were carried out using standard techniques, which are well known and routine to those of skill in the art, except where otherwise described in detail. Routine molecular biology techniques of the following examples can be carried out as 5 described in standard laboratory manuals, such as Sambrook et al., *MOLECULAR CLONING: A LABORATORY MANUAL*, 2nd Ed.; Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989).

All parts or amounts set out in the following examples are by weight, unless otherwise specified.

10 Unless otherwise stated size separation of fragments in the examples below was carried out using standard techniques of agarose and polyacrylamide gel electrophoresis ("PAGE") in Sambrook et al., *MOLECULAR CLONING: A LABORATORY MANUAL*, 2nd Ed., Cold Spring Harbor Laboratory Press, Cold Spring Harbor, N.Y. (1989) and numerous other references such as, for instance, by Goeddel 15 et al., *Nucleic Acids Res.* 8: 4057 (1980).

Unless described otherwise, ligations were accomplished using standard buffers, incubation temperatures and times, approximately equimolar amounts of the DNA fragments to be ligated and approximately 10 units of T4 DNA ligase ("ligase") per 0.5 microgram of DNA.

20

Example I: Isolation of DNA Coding for Novel Proteins from *Zea mays*

The polynucleotide having the myo-inositol 1-phosphate synthase DNA sequence was obtained from the sequencing of a library of cDNA clones prepared from maize embryos isolated 15 days after pollination. The polynucleotide having 25 the myo-inositol monophosphatase-3 DNA sequence was obtained from the sequencing of a library of cDNA clones prepared from maize immature ears. The polynucleotide having the myo-inositol 1,3,4-triphosphate 5,6-kinase DNA sequence was obtained from the sequencing of a library of cDNA clones prepared from maize tassel shoots. The polynucleotide having the phosphatidylinositol-3-kinase DNA 30 sequence was obtained from the sequencing of a library of cDNA clones prepared from germinating maize seeds. Total RNA was isolated from this tissue using

- 53 -

standard protocols and enriched for mRNA by selection with oligo dT, again by standard protocols. This mRNA was then used as template to synthesize complementary DNA (cDNA) using the enzyme reverse transcriptase by conventional methods. The resulting strand of cDNA was then converted to double-stranded pieces of cDNA and ligated into the cloning vector pSPORT using conventional ligation/transformation methods. Individual colonies were then selected and plasmid DNA prepared from each. This plasmid DNA was then denatured and used as template in dideoxynucleotide sequencing reactions. By sequencing the individual clones thus identified with sequencing primers designed from the original sequence it is then possible to extend the sequence in both directions to determine the full gene sequence. Suitable techniques are described by Maniatis, T., Fritsch, E.F. and Sambrook *et al.*, *MOLECULAR CLONING, A LABORATORY MANUAL*, 2nd Ed.; Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York (1989). (See Screening By Hybridization 1.90 and Sequencing Denatured Double-Stranded DNA Templates 13.70). The sequences were compared to those sequences available in public databases (i.e., Genbank) to determine homologies/gene identification. In some cases the sequencing data from two or more clones containing overlapping segments of DNA were used to construct the contiguous DNA sequence below.

20

Example 2: Construction of Expression Cassettes for Homology-Dependent Gene Silencing of Phytate Biosynthetic Enzyme Expression

To facilitate manipulations of this trait in conventional breeding programs, the expression cassette described above is used in homologous gene silencing (i.e. Knockout) of the endogenous phytate biosynthetic enzyme polynucleotides by using the embryo-preferred promoter globulin-1 to drive expression of the genes.

Plant expression cassettes are made using the embryo-preferred promoter globulin-1 to drive expression of the phytate biosynthetic enzyme polynucleotides. Globulin-1 termination sequences are also included in this cassette. The entire expression cassette is cloned into a pUC based plasmid vector for easy manipulation in *E. coli*. This construct is used for particle bombardment

transformation of corn in conjunction with another expression construct which includes a selectable marker (for example Pat, PHP8092→ Ubi::mo-PAT::ubi). For Agrobacterium-mediated transformation, a plasmid is moved into an appropriate binary vector containing both left and right border sequences to facilitate DNA transfer into the target genome.

This polynucleotide, encoding the inventive polypeptides, when made to be non-functional in plants, results in a reduction in phytic acid and an increase in non-phytate phosphorus levels. This can be demonstrated using the transposable element Mu. Maize lines are confirmed as having a Mu element inserted into the 10 coding region of the phytate biosynthetic enzyme polynucleotides. Extensive genetics are done on this phenotype demonstrating it to be transmitted to progeny as a homozygous recessive trait.

Example 3: Transformation of Maize

15 The inventive polynucleotides contained within a vector are transformed into embryogenic maize callus by particle bombardment. Transgenic maize plants are produced by bombardment of embryogenically responsive immature embryos with tungsten particles associated with DNA plasmids. The plasmids consist of a selectable and an unselectable marker gene.

20

Preparation of Particles

Fifteen mg of tungsten particles (General Electric), 0.5 to 1.8 μ , preferably 1 to 1.8 μ , and most preferably 1 μ , are added to 2 ml of concentrated nitric acid. This suspension was sonicated at 0°C for 20 minutes (Branson Sonifier Model 450, 40% output, constant 25 duty cycle). Tungsten particles are pelleted by centrifugation at 10000 rpm (Biofuge) for one minute, and the supernatant is removed. Two milliliters of sterile distilled water are added to the pellet, and brief sonication is used to resuspend the particles. The suspension is pelleted, one milliliter of absolute ethanol is added to the pellet, and brief sonication is used to resuspend the particles. Rinsing, pelleting, and resuspending of 30 the particles is performed two more times with sterile distilled water, and finally the

particles are resuspended in two milliliters of sterile distilled water. The particles are subdivided into 250-ml aliquots and stored frozen.

Preparation of Particle-Plasmid DNA Association

5 The stock of tungsten particles are sonicated briefly in a water bath sonicator (Branson Sonifier Model 450, 20% output, constant duty cycle) and 50 ml is transferred to a microfuge tube. Equimolar amounts of selectable and unselectable plasmid DNA are added to the particles for a final DNA amount of 0.1 to 10 mg in 10 ml total volume, and briefly sonicated. Preferably, 1 mg total DNA is used. Specifically, 4.9 ml of PHP
10 8092 (Ubiquitin::ubiquitin intron::mo-PAT::35S CaMV, 6.329 kbp)) plus 5.1 ml of (globulin1::mi1ps::globulin1), where any phytate biosynthetic enzyme polynucleotide can replace mi1ps, both at 0.1 mg/ml in TE buffer, are added to the particle suspension. Fifty microliters of sterile aqueous 2.5 M CaCl₂ are added, and the mixture is briefly sonicated and vortexed. Twenty microliters of sterile aqueous 0.1 M spermidine are
15 added and the mixture is briefly sonicated and vortexed. The mixture is incubated at room temperature for 20 minutes with intermittent brief sonication. The particle suspension is centrifuged, and the supernatant is removed. Two hundred fifty microliters of absolute ethanol are added to the pellet, followed by brief sonication. The suspension is pelleted, the supernatant is removed, and 60 ml of absolute ethanol are
20 added. The suspension is sonicated briefly before loading the particle-DNA agglomeration onto macrocarriers.

Preparation of Tissue

Immature embryos of maize variety High Type II are the target for particle
25 bombardment-mediated transformation. This genotype is the F₁ of two purebred genetic lines, parents A and B, derived from the cross of two known maize inbreds, A188 and B73. Both parents are selected for high competence of somatic embryogenesis, according to Armstrong et al., Maize Genetics Coop. News 65: 92 (1991).

Ears from F₁ plants are selfed or sibbed, and embryos are aseptically dissected
30 from developing caryopses when the scutellum first became opaque. This stage occurs about 9-13 days post-pollination, and most generally about 10 days post-pollination, depending on growth conditions. The embryos are about 0.75 to 1.5 millimeters long.

Ears are surface sterilized with 20-50% Clorox for 30 minutes, followed by three rinses with sterile distilled water.

Immature embryos are cultured with the scutellum oriented upward, on embryogenic induction medium comprised of N6 basal salts, Eriksson vitamins, 0.5 mg/l thiamine HCl, 30 gm/l sucrose, 2.88 gm/l L-proline, 1 mg/l 2,4-dichlorophenoxyacetic acid, 2 gm/l Gelrite, and 8.5 mg/l AgNO₃. Chu *et al.*, Sci. Sin. 18: 659 (1975); Eriksson, Physiol. Plant 18: 976 (1965). The medium is sterilized by autoclaving at 121°C for 15 minutes and dispensed into 100 X 25 mm Petri dishes. AgNO₃ is filter-sterilized and added to the medium after autoclaving. The tissues are cultured in complete darkness at 28°C. After about 3 to 7 days, most usually about 4 days, the scutellum of the embryo swells to about double its original size and the protuberances at the coleorhizal surface of the scutellum indicated the inception of embryogenic tissue. Up to 100% of the embryos displayed this response, but most commonly, the embryogenic response frequency is about 80%.

When the embryogenic response is observed, the embryos are transferred to a medium comprised of induction medium modified to contain 120 gm/l sucrose. The embryos are oriented with the coleorhizal pole, the embryogenically responsive tissue, upwards from the culture medium. Ten embryos per Petri dish are located in the center of a Petri dish in an area about 2 cm in diameter. The embryos are maintained on this medium for 3-16 hour, preferably 4 hours, in complete darkness at 28°C just prior to bombardment with particles associated with plasmid DNAs containing the selectable and unselectable marker genes.

To effect particle bombardment of embryos, the particle-DNA agglomerates are accelerated using a DuPont PDS-1000 particle acceleration device. The particle-DNA agglomeration is briefly sonicated and 10 ml were deposited on macrocarriers and the ethanol is allowed to evaporate. The macrocarrier is accelerated onto a stainless-steel stopping screen by the rupture of a polymer diaphragm (rupture disk). Rupture is effected by pressurized helium. The velocity of particle-DNA acceleration is determined based on the rupture disk breaking pressure. Rupture disk pressures of 200 to 1800 psi are used, with 650 to 1100 psi being preferred, and about 900 psi being most highly preferred. Multiple disks are used to effect a range of rupture pressures.

The shelf containing the plate with embryos is placed 5.1 cm below the bottom of the macrocarrier platform (shelf #3). To effect particle bombardment of cultured immature embryos, a rupture disk and a macrocarrier with dried particle-DNA agglomerates are installed in the device. The He pressure delivered to the device is 5 adjusted to 200 psi above the rupture disk breaking pressure. A Petri dish with the target embryos is placed into the vacuum chamber and located in the projected path of accelerated particles. A vacuum is created in the chamber, preferably about 28 in Hg. After operation of the device, the vacuum is released and the Petri dish is removed.

Bombarded embryos remain on the osmotically-adjusted medium during 10 bombardment, and 1 to 4 days subsequently. The embryos are transferred to selection medium comprised of N6 basal salts, Eriksson vitamins, 0.5 mg/l thiamine HCl, 30 gm/l sucrose, 1 mg/l 2,4-dichlorophenoxyacetic acid, 2 gm/l Gelrite, 0.85 mg/l Ag NO₃ and 15 3 mg/l bialaphos (Herbiace, Meiji). Bialaphos is added filter-sterilized. The embryos are subcultured to fresh selection medium at 10 to 14 day intervals. After about 7 weeks, embryogenic tissue, putatively transformed for both selectable and unselected 20 marker genes, proliferates from about 7% of the bombarded embryos. Putative transgenic tissue is rescued, and that tissue derived from individual embryos is considered to be an event and is propagated independently on selection medium. Two cycles of clonal propagation are achieved by visual selection for the smallest contiguous fragments of organized embryogenic tissue.

A sample of tissue from each event is processed to recover DNA. The DNA is restricted with a restriction endonuclease and probed with primer sequences designed 25 to amplify DNA sequences overlapping the phytate biosynthetic enzymes and non-phytate biosynthetic enzyme portion of the plasmid. Embryogenic tissue with amplifiable sequence is advanced to plant regeneration.

For regeneration of transgenic plants, embryogenic tissue is subcultured to a medium comprising MS salts and vitamins (Murashige & Skoog, Physiol. Plant 15: 473 (1962)), 100 mg/l myo-inositol, 60 gm/l sucrose, 3 gm/l Gelrite, 0.5 mg/l zeatin, 1 mg/l 30 indole-3-acetic acid, 26.4 ng/l cis-trans-abscissic acid, and 3 mg/l bialaphos in 100 X 25 mm Petri dishes, and is incubated in darkness at 28°C until the development of well-formed, matured somatic embryos can be seen. This requires about 14 days. Well-

formed somatic embryos are opaque and cream-colored, and are comprised of an identifiable scutellum and coleoptile. The embryos are individually subcultured to a germination medium comprising MS salts and vitamins, 100 mg/l myo-inositol, 40 gm/l sucrose and 1.5 gm/l Gelrite in 100 X 25 mm Petri dishes and incubated under a 5 16 hour light:8 hour dark photoperiod and 40 meinstein m^2sec^{-1} from cool-white fluorescent tubes. After about 7 days, the somatic embryos have germinated and produced a well-defined shoot and root. The individual plants are subcultured to germination medium in 125 X 25 mm glass tubes to allow further plant development. The plants are maintained under a 16 hour light:8 hour dark photoperiod and 40 10 meinstein m^2sec^{-1} from cool-white fluorescent tubes. After about 7 days, the plants are well-established and are transplanted to horticultural soil, hardened off, and potted into commercial greenhouse soil mixture and grown to sexual maturity in a greenhouse. An elite inbred line is used as a male to pollinate regenerated transgenic plants.

15 **Example 4: Identification of High Phosphorus Transgenic Corn Lines**

The resulting transformants are screened for elevated levels of inorganic phosphorus using a simple colorimetric assay. Individual transgenic kernels are crushed in the well of a megatiter breeding tray using a hydraulic press to 2000 psi. The crushed kernels are then soaked in 2 ml of 1 N H₂SO₄ for 2 hours at room 20 temperature. Color development is then initiated by the addition of 4 ml of developing solution (1 part 10% ascorbic acid, 6 parts 0.42% ammonium molybdate in 1N H₂SO₄) to each crushed kernel. Kernels are scored after 30 minute incubation at room temperature as either positive (blue) or negative (clear). Positive in this instance refers to a high level of inorganic phosphorus. This 25 protocol is a modified version of what is described in Chen et al., Anal. Chem. 28:1756 (1956). Those transformants which are screened as positive with the colorimetric assay will then be subjected to more rigorous analyses to include Southern, Northern and Western blotting and quantitation of phytic acid levels.

Confirmation of Elevated Non-Phytate Phosphorus Levels

The present transgenics preferably have non-phytate phosphorus levels in excessive of the natural levels of available phosphorus for the plant species of interest. In respect to corn it is preferred to have non-phytate phosphorus levels of about 0.175%, more preferably about 0.2% and most preferably about 0.225% or higher. These percentages being base on %wt/wt at a 13% moisture basis for both corn seed. With respect to soybeans, it is preferred to have non-phytate phosphorus levels of about 0.47%, more preferably about 0.49% and most preferably about 0.51%. These latter percentage being based on the weight of non-phytate phosphorus/ (non phytate P /gram of meal on a 13% moisture basis).

Each plant identified as a potential high phosphorus transgenic is tested again to confirm the original elevated phosphorus reading. Some putative transgenics may not confirm for the elevated phosphorus trait. Those which confirm are selected on the basis of uniformity for the elevated phosphorus trait.

15 Confirmation of Reduced Phytate Levels

To determine whether high non-phytate phosphorus transgenics are also characterized by reduced levels of phytate, the following method is used to quantify the level of phytic acid in a tested sample.

The sample is ground, placed in a conical plastic centrifuge tube and treated with hydrochloric acid. It is homogenized with polytron, and extracted at room temperature with vortexing. The extracted sample is placed in a clinical centrifuge at 2500 RPM for 15 minutes. 2.5 ml of the supernatant is removed and added to 25 ml water. The sample is washed through a SAX® column. The column is washed with HCl, eluted and evaporated to dryness. The dried sample is resuspended in water and filtered through a 0.45 micrometer syringe tip filter into a vial. 10 to 20 microliters of samples are prepared to inject into an HPLC column.

The eluting solvent is prepared by mixing 515 ml of methanol, 485 ml of double distilled water, 8 ml tetrabutyl ammonium hydroxide 40% (TBAH), 200 microliters of 10 N, (5 M) sulfuric acid, 0.5 ml formic acid and 1-3 mg phytic acid. Phytic acid is prepared by placing 16 mg of sodium phytate in 5 ml of water. This solution is placed on Dowex ion exchange resin (1 ml Dowex-50 acid form on glass

wool in 5 ml pipette tip). This is rinsed with 1-2 ml water, and the filtrate brought to 10 ml with water. Concentration is 1 mg/ml phytic acid. 2 ml is used for 1 liter of solvent. pH of the solvent is adjusted to 4.10 +/- 0.05 with 10 N sulfuric acid. Chromatography is accomplished by pumping the sample through a Hamilton PRP-5 1 reverse phase HPLC column heated to 40 degrees centigrade at a rate of 1 ml per minute. The detection of inositol phosphate is accomplished with a refractive index detector (Waters), which is auto-zeroed at least two (2) minutes before each run.

The confirmed high phosphorus transgenics are tested in this manner. Some, but not all, of the mutants evaluated in this way are confirmed to be low in 10 phytate.

Sequence Description

- SEQ ID NO:1 PHOSPHATIDYLINOSITOL-3-KINASE cDNA
- SEQ ID NO:2 PHOSPHATIDYLINOSITOL-3-KINASE POLYPEPTIDE
- 15 SEQ ID NO:3 PHOSPHATIDYLINOSITOL-3-KINASE PRIMER
- SEQ ID NO:4 PHOSPHATIDYLINOSITOL-3-KINASE PRIMER
- SEQ ID NO:5 MYO-INOSITOL 1,3,4-TRIPHOSPHATE 5/6-KINASE cDNA
- SEQ ID NO:6 MYO-INOSITOL 1,3,4-TRIPHOSPHATE 5/6-KINASE POLYPEPTIDE
- SEQ ID NO:7 MYO-INOSITOL 1,3,4-TRIPHOSPHATE 5/6-KINASE GENERIC
- 20 SEQ ID NO:8 MYO-INOSITOL 1,3,4-TRIPHOSPHATE 5/6-KINASE PRIMER
- SEQ ID NO:9 MYO-INOSITOL 1,3,4-TRIPHOSPHATE 5/6-KINASE PRIMER
- SEQ ID NO:10 MYO-INOSITOL 1-PHOSPHATE SYNTHASE cDNA
- SEQ ID NO:11 MYO-INOSITOL 1-PHOSPHATE SYNTHASE POLYPEPTIDE
- SEQ ID NO:12 MYO-INOSITOL 1-PHOSPHATE SYNTHASE PRIMER
- 25 SEQ ID NO:13 MYO-INOSITOL 1-PHOSPHATE SYNTHASE PRIMER
- SEQ ID NO:14 MYO-INOSITOL 1-PHOSPHATE SYNTHASE GENOMIC
- SEQ ID NO:15 MYO-INOSITOL 1-PHOSPHATE SYNTHASE GENOMIC
- SEQ ID NO:16 MYO-INOSITOL MONOPHOSPHATE-3 cDNA
- SEQ ID NO:17 MYO-INOSITOL MONOPHOSPHATE-3 POLYPEPTIDE
- 30 SEQ ID NO:18 MYO-INOSITOL MONOPHOSPHATE-3 PRIMER
- SEQ ID NO:19 MYO-INOSITOL MONOPHOSPHATE-3 PRIMER

What is claimed is:

1. An isolated polynucleotide comprising a member selected from the group consisting of:
 - 5 (a) a polynucleotide encoding a polypeptide comprising SEQ ID NOS. 2, 6, 11, 17 or complement thereof;
 - (b) a polynucleotide of at least 25 nucleotides in length which selectively hybridizes under stringent conditions to a polynucleotide of SEQ ID NOS: 1, 5, 7, 10, 14, 15, 16 or a complement thereof, wherein the hybridization conditions include a wash step in 0.1X SSC at 60°C;
 - 10 (c) a polynucleotide having a sequence of a nucleic acid amplified from a *Zea mays* nucleic acid library using the primers of SEQ ID NOS: 3- 4, 8-9, 12-13, or 18-19;
 - (d) a polynucleotide having at least 75% sequence identity to SEQ ID NO: 1, at least 60% sequence identity to SEQ ID NO: 5, at least 80% sequence identity to SEQ ID NO: 10, or at least 70% sequence identity to SEQ ID NO: 16, wherein the % sequence identity is based on the entire coding region and is determined by the GAP program where the gap creation penalty = 50 and the gap extension penalty = 3; and
 - 15 (e) a polynucleotide comprising at least 20 contiguous bases of the polynucleotide of (a) through (d), or complement thereof.
2. The polynucleotide of Claim 1 wherein the polynucleotide is DNA.
- 25 3. The polynucleotide of Claim 1 wherein the polynucleotide is RNA.
4. The polynucleotide of Claim 2 comprising SEQ ID NOS: 1, 5, 7, 10, 14, 15, 16 or a complement thereof.

5. An isolated polynucleotide from maize that encodes phosphatidylinositol 3-kinase, myo-inositol monophosphatase-3, myo-inositol 1,3,4-triphosphate 5/6 kinase or myo-inositol 1-phosphate synthase.
- 5 6. A vector comprising the DNA of Claim 2.
7. An expression cassette, comprising the polynucleotide of claim 1 operably linked to a promoter.
- 10 8. The expression cassette of Claim 7, wherein the nucleic acid is operably linked in antisense orientation to the promoter
9. A host cell comprising the vector of Claim 6.
- 15 10. A process for producing a phosphatidylinositol 3-kinase, myo-inositol monophosphatase-3, myo-inositol 1,3,4-triphosphate 5/6 kinase or myo-inositol 1-phosphate synthase polypeptide comprising: culturing the host cell of Claim 9 under conditions sufficient for the expression of the polypeptide encoded by the host cell and recovering the polypeptide so produced.
- 20 11. A process for producing a cell which expresses a phosphatidylinositol 3-kinase, myo-inositol monophosphatase-3, myo-inositol 1,3,4-triphosphate 5/6 kinase or myo-inositol 1-phosphate synthase polypeptide comprising transforming or transfecting the cell with the vector of Claim 6 such that the cell expresses the polypeptide encoded by the cDNA contained in the vector.
- 25 12. An isolated polypeptide comprising an amino acid sequence which has at least 80% sequence identity to SEQ ID NO: 2, at least 35% sequence identity to SEQ ID NO: 6, at least 90% sequence identity to SEQ ID NO: 11 or at least 80% sequence identity to SEQ ID NO: 17, wherein the % sequence identity is based on the entire sequence and is determined by the GAP

program where the gap creation penalty = 12 and the gap extension penalty = 4.

13. The isolated polypeptide of claim 12 which has at least 85% sequence identity to SEQ ID NO: 2 and a deduced molecular weight of about 94.1 kDa.
- 5 14. The isolated polypeptide of claim 12 which has at least 40% sequence identity to SEQ ID NO: 6 and a deduced molecular weight of about 41.3 kDa.
- 10 15. The isolated polypeptide of claim 12 which has at least 95% sequence identity to SEQ ID NO: 11 and a deduced molecular weight of about 59.7 kDa.
16. The isolated polypeptide of claim 12 which has at least 85% sequence identity to SEQ ID NO: 17 and a deduced molecular weight of about 31.2 kDa.
- 15 17. The isolated polypeptide of Claim 12 comprising the sequence of SEQ ID NOS: 2, 6, 11 or 17.
18. An antibody against the polypeptide of Claim 12.
- 20 19. An antagonist which inhibits the activity of the polypeptide of Claim 12.
- 20 21. The plant according to Claim 20 further characterized as having a decreased level of phytic acid when compared to a non-transformed parental plant.
- 25 22. The plant according to Claim 20 further characterized as having an increased level of non-phytic acid phosphorous when compared to a non-transformed parental plant.
- 30

23. A seed produced by the plant of Claim 20.
24. A transgenic plant cell transformed with the DNA of Claim 2.
25. An isolated polynucleotide comprising a member selected from the group consisting of:
 - (a) a polynucleotide of at least 25 nucleotides in length which selectively hybridizes under stringent conditions to a polynucleotide of SEQ ID NOS: 20-31 or a complement thereof, wherein the hybridization conditions include a wash step in 0.1X SSC at 60°C;
 - (b) a polynucleotide having at least 80% sequence identity to SEQ ID NOS: 20-31, wherein the % sequence identity is based on the entire coding region and is determined by the GAP program where the gap creation penalty = 50 and the gap extension penalty = 3; and
 - (c) a polynucleotide comprising at least 20 contiguous bases of the polynucleotide of (a) or (b), or complement thereof.
26. The polynucleotide of Claim 2 comprising SEQ ID NOS: 20-31 or a complement thereof.
27. A method for improving animal performance comprising feeding plants and plant parts to animals.

SEQUENCE LISTING

<110> Pioneer Hi-Bred International, Inc.

<120> Genes Controlling Phytate Metabolism in Plants and Uses Thereof

<130> 0706

<150> 60/055,446
<151> 1997-06-11

<150> 60/055,526
<151> 1997-08-08

<150> 60/053,944
<151> 1997-07-28

<160>

<170> FastSEQ for Windows Version 3.0

<210> 1
<211> 3252
<212> DNA
<213> Zea mays

<220>

<221> CDS

<222> (258)

45 <400> 1
 gtcgacccac gcgtccgctc gccgcgggag tcacgcaacc gccgtctcct cgccggcacg 60
 cttcgcgcgc: gccgcctctc tcctcctcgt ctcaaccgcc gcctgcacac gcagaaaaagg 120
 agggagaata agaggatcaag caaaccccaa gccctccact cgtcgccccc tgatgcaatc 180
 gccccaccccg cctccgccccg cccgcgttc tcctcacctt cctctcccgc gacatctcag 240
 50 ttcttcatca ccaaaag atg gtc ggc ggc ggc aac gag ttc cgt ttc ttc 290
 Met Val Gly Gly Gly Asn Glu Phe Arg Phe Phe
 1 5 10

55 ttg tcc tgc gac atc agc cac ccg ctt gcc ttc cgt gtt ctc cac gca 338
 Leu Ser Cys Asp Ile Ser His Pro Leu Ala Phe Arg Val Leu His Ala
 15 20 25

gaa cat atc ttg ttg acc gac caa aaa gtc cca gag ctc ttt gtt gag 386
 Glu His Ile Leu Leu Thr Asp Gln Lys Val Pro Glu Leu Phe Val Glu
 60 30 35 40

	tgc aag cta tac atc gat ggg atc caa ttt ggg ttg cct gta aaa aca	434
	Cys Lys Leu Tyr Ile Asp Gly Ile Gln Phe Gly Leu Pro Val Lys Thr	
45	45 50 55	
5	agg ttg gaa cct tct gga ccg aaa tac tgt tgg aat gag ctc ata aca	482
	Arg Leu Glu Pro Ser Gly Pro Lys Tyr Cys Trp Asn Glu Leu Ile Thr	
60	60 65 70 75	
10	tta agt acc aaa tac agg gac cta aca tcc ctt tgg cag ctt gca ttt	530
	Leu Ser Thr Lys Tyr Arg Asp Leu Thr Ser Leu Ser Gln Leu Ala Phe	
	80 85 90	
15	acg ggg tgg gat gtc tca tct ggt gag aac cct gag gtt gtc ggt gga	578
	Thr Val Trp Asp Val Ser Ser Gly Glu Asn Pro Glu Val Val Gly Gly	
	95 100 105	
20	gcc acc ata ttt ctt ttt aac agc aaa agg cag ctt aaa aca gga aga	626
	Ala Thr Ile Phe Leu Phe Asn Ser Lys Arg Gln Leu Lys Thr Gly Arg	
	110 115 120	
25	cag aag ctg cgg ctg tgg ccc aca aag gag gca gat gga gga gtc ccc	674
	Gln Lys Leu Arg Leu Trp Pro Thr Lys Glu Ala Asp Gly Gly Val Pro	
	125 130 135	
30	acc aca act cct ggc aag gtt cct agg aat gag agg ggt gag ata gaa	722
	Thr Thr Pro Gly Lys Val Pro Arg Asn Glu Arg Gly Glu Ile Glu	
	140 145 150 155	
35	cgt ttg gaa agg ctt gtt aac aag tat gag aga ggg cag ata caa cat	770
	Arg Leu Glu Arg Leu Val Asn Lys Tyr Glu Arg Gly Gln Ile Gln His	
	160 165 170	
40	gtt gat tgg ctt gat cgt ctt gcc ttc agt gct atg gac aaa gct atg	818
	Val Asp Trp Leu Asp Arg Leu Ala Phe Ser Ala Met Asp Lys Ala Met	
	175 180 185	
45	gaa aaa gag tgt gag agg aag gcc aat ttg tac cct agt ctg gtt gtt	866
	Glu Lys Glu Cys Glu Arg Lys Ala Asn Leu Tyr Pro Ser Leu Val Val	
	190 195 200	
50	gaa ttg tgc agt ttc gaa cat aga att gtc ttc cag gaa tct gga gca	914
	Glu Leu Cys Ser E.. Glu His Arg Ile Val Phe Gln Glu Ser Gly Ala	
	205 210 215	
55	aat ttt tat aca ccg gcc cca gta tca tta tca aat gaa ctg gtt act	962
	Asn Phe Tyr Thr Pro Ala Pro Val Ser Leu Ser Asn Glu Leu Val Thr	
	220 225 230 235	
60	gta tgg gac cct gaa ctt gga aga acc aat cca tct gag cac aag cag	1010
	Val Trp Asp Pro Glu Leu Gly Arg Thr Asn Pro Ser Glu His Lys Gln	
	240 245 250	
55	tta aag ctt gct aag agc ttg act cgt ggg ata gtt gat aga gat cta	1058
	Leu Lys Leu Ala Lys Ser Leu Thr Arg Gly Ile Val Asp Arg Asp Leu	
	255 260 265	
60	aaa cca agc tca aat gag aga aag tta sta caa aca att att aag ttt	1106
	Lys Pro Ser Ser Asn Glu Arg Lys Leu Leu Gln Thr Ile Ile Lys Phe	
	270 275 280	

285	cct cct aca cgc acc ttg gaa gtg gat gag aag caa ttg gtg tgg aag Pro Pro Thr Arg Thr Leu Glu Val Asp Glu Lys Gln Leu Val Trp Lys 290 295	1154
300	5 stt cgt ttc tct ttg atg tct gag aag aaa gct cta acg aaa ttt gtc Phe Arg Phe Ser Leu Met Ser Glu Lys Lys Ala Leu Thr Lys Phe Val 305 310 315	1202
320	10 cgc tca gtg gat tgg agt gat aac caa gaa gct aag caa gct gtt gag Arg Ser Val Asp Trp Ser Asp Asn Gln Glu Ala Lys Gln Ala Val Glu 325 330 335	1250
335	15 ttg att gga aag tgg gaa atg att gat gtg gct gat gca cta gag ctt Leu Ile Gly Lys Trp Glu Met Ile Asp Val Ala Asp Ala Leu Glu Leu 340 345	1298
350	20 stc tca cct gat ttt gaa agc gac gaa gtt ggt tat gct gtc agc Leu Ser Pro Asp Phe Glu Ser Asp Glu Val Arg Gly Tyr Ala Val Ser 355 360	1346
365	25 gta ctt gaa agg gct gat gat gaa gaa tta cag tgc tat tta ctc cag Val Leu Glu Arg Ala Asp Asp Glu Glu Leu Gln Cys Tyr Leu Leu Gln 370 375	1394
380	30 ctc ttt ctt gta aac cgt gct ttg tcc aac atc gaa att gct agc ttc Leu Phe Leu Val Asn Arg Ala Leu Ser Asn Ile Glu Ile Ala Ser Phe 385 390 395	1442
400	35 ctc cgg tgg tat ata tta gtt gag ctt cac agt cct gca tat gca aga Leu Arg Trp Tyr Ile Leu Val Glu Leu His Ser Pro Ala Tyr Ala Arg 415 420 425	1538
430	40 cga tat tat ggc aca tat gac atg ctt gaa aac agt atg atg aaa ttg Arg Tyr Tyr Gly Thr Tyr Asp Met Leu Glu Asn Ser Met Met Lys Leu 435 440	1586
445	45 gtt ggt agg gag gat ggg gat gaa gat gga ctt cga ctg tgg cag agt Val Gly Arg Glu Asp Gly Asp Glu Asp Gly Phe Arg Leu Trp Gln Ser 450 455	1634
460	50 tta acc cgg cag aca gac ctc act gct caa ttg tgt tct att atg aag Leu Thr Arg Gln Thr Asp Leu Thr Ala Gln Leu Cys Ser Ile Met Lys 465 470 475	1682
480	55 gat gta aga aat gta aga ggt agc gca caa aag aaa att gaa aaa ttg Asp Val Arg Asn Val Arg Gly Ser Ala Gln Lys Lys Ile Glu Lys Leu 485 490	1730
495	60 agg cag cta tta tca gga gtt ttc agt gag ctt aca aac ttt gat gag Arg Gln Leu Leu Ser Gly Val Phe Ser Glu Leu Thr Asn Phe Asp Glu 500 505	1778
510	55 cca att cgt tca cca tta gca cca act ctt stc cta aca gga gtt gtg Pro Ile Arg Ser Pro Leu Ala Pro Thr Leu Leu Thr Gly Val Val 515 520	1826

	cct caa gaa tcg tct ata ttt aag agt gcc ttg aac cct ttg cgc ctg Pro Gln Glu Ser Ser Ile Phe Lys Ser Ala Leu Asn Pro Leu Arg Leu 525 530 535	1874
5	aca ttt aaa aca gca aat ggc gga aca tcc aag att att tac aaa aag Thr Phe Lys Thr Ala Asn Gly Gly Thr Ser Lys Ile Ile Tyr Lys Lys 540 545 550 555	1922
10	ggc gat gac ctc cgg caa gat cag ttg gtt att caa acg gtt tct ttg Gly Asp Asp Leu Arg Gln Asp Gln Leu Val Ile Gln Thr Val Ser Leu 560 565 570	1970
15	atg gac cga cta ctc aaa cta gaa aat cta gat ttg cac ctt act cca Met Asp Arg Leu Leu Lys Leu Glu Asn Leu Asp Leu His Leu Thr Pro 575 580 585	2018
20	taa tgg gtt ctt gca aat gga caa gat gaa ggg atg ctt gaa ttt att Tyr Arg Val Leu Ala Thr Gly Gln Asp Glu Gly Met Leu Glu Phe Ile 590 595 600	2066
25	agt tcc agt tct ctt gca cag att cta tca gaa cat cgc agt att aca Ser Ser Ser Leu Ala Gln Ile Leu Ser Glu His Arg Ser Ile Thr 605 610 615	2114
30	agt tac cta cag aag ttc cat ctt gat gag gat ggt cct ttt ggt ata Ser Tyr Leu Gln Lys Phe His Kaa Asp Glu Asp Gly Pro Phe Gly Ile 620 625 630 635	2162
35	acg gct caa tgt ttg gag aca ttc ata aaa agc tgc gcc ggt tac tct Thr Ala Gln Cys Leu Glu Thr Phe Ile Lys Ser Cys Ala Gly Tyr Ser 640 645 650	2210
40	gtc att aca tac ata ttg ggg gtt gga gac agg cat ctg gat aat ctt Val Ile Thr Tyr Ile Leu Gly Val Gly Asp Arg His Leu Asp Asn Leu 655 660 665	2258
45	ctt cta act gat gat gga cgc ctt ttt cat gtt gac ttt gct ttt atc Leu Leu Thr Asp Asp Gly Arg Leu Phe His Val Asp Phe Ala Phe Ile 670 675 680	2306
50	ctt ggg cga gac cca aag cca ttt ccg cca ccg atg aag ttg tgt aag Leu Gly Arg Asp Pro Lys Pro Phe Pro Pro Pro Met Lys Leu Cys Lys 685 690 695	2354
55	gaa atg gtt gag gcc atg ggt gca gaa agc caa tat tac aca agg Glu Met Val Glu Ala Met Gly Gly Ala Glu Ser Gln Tyr Tyr Thr Arg 700 705 710 715	2402
60	ttc aag tcc tac tgc tgc gaa gca tac aac att ctg agg aag tcc agc Phe Lys Ser Tyr Cys Cys Glu Ala Tyr Asn Ile Leu Arg Lys Ser Ser 720 725 730	2450
	agt ctc att ttg aat cta ttc aag ctg atg gag cga tca ggc att ccg Ser Leu Ile Leu Asn Leu Phe Lys Leu Met Glu Arg Ser Gly Ile Pro 735 740 745	2498
	gac atc tct gcc gat gaa agc gga ggt ctc aag ctc cag gag aaa ttc Asp Ile Ser Ala Asp Glu Ser Gly Gly Leu Lys Leu Gln Glu Lys Phe 750 755 760	2546

15	cggttgatctggacgacgaggaggtatataatccatccatcagatctt Arg Leu Asp Leu Asp Asp Glu Glu Ala Ile His Phe Phe Gln Asp Leu 765 770 775	2594
20	atc aac gat agc gtg agt gct ctg ttc cct caa atg gtt gag acc atc Ile Asn Asp Ser Val Ser Ala Leu Phe Pro Gln Met Val Glu Thr Ile 780 785 790 795	2642
25	cat aga tgg gct caa tat tgg cgg taacacaagc taatgtcgta gaagcaagtg His Arg Trp Ala Gln Tyr Trp Arg 800	2696
30	tgaatctgta catgctgact gtcacaagcc acggattttaa gcgagaaaacg acacttggatg gatggaaagct taggcgcctta gcatttgggg ttcaagctgc nccgcatctg cgaattttatt gggctgtgc agggcatggg caatcttctt cgtgccggg acacccagga attcgggttg tcagttgtca cttgtgatag tagaattccg tcacgcactg ctgtagacct atggcattc gtcagatgta tatatgcgtt aatgtataaa atcaacttca gtagcaaatt tggtaatacc gaaatacgtg atggtttagg gcctgtttgt ttaccccatg gattatataa tctggattat ttttggagga ttatataatc tggatttat aatctgagta gttctgtttg tttacccaga tttttgagt tgtaatagg attctttgt atgaggaaga aaaaatgccc ctctatattt gtacttaggtt gaaactcata tatgagatga acaatgtaac aaaaaaaaaa aaaaaaaaaa aaaaaaaaaggg cggcccg	2756 2816 2876 2936 2996 3056 3116 3176 3236 3252
35	<210> 2 <211> 803 <212> PRT <213> Zea mays	
40	<400> 2 Met Val Gly Gly Gly Asn Glu Phe Arg Phe Phe Leu Ser Cys Asp Ile 1 5 10 15 Ser His Pro Leu Ala Phe Arg Val Leu His Ala Glu His Ile Leu Leu 20 25 30 Thr Asp Gln Lys Val Pro Glu Leu Phe Val Glu Cys Lys Leu Tyr Ile 35 40 45 Asp Gly Ile Gln Phe Gly Leu Pro Val Lys Thr Arg Leu Glu Pro Ser 50 55 60 Gly Pro Lys Tyr Cys Trp Asn Glu Leu Ile Thr Leu Ser Thr Lys Tyr 65 70 75 80 Arg Asp Leu Thr Ser Leu Ser Gln Leu Ala Phe Thr Val Trp Asp Val 85 90 95 Ser Ser Gly Glu Asn Pro Glu Val Val Gly Gly Ala Thr Ile Phe Leu 100 105 110 Phe Asn Ser Lys Arg Gln Leu Lys Thr Gly Arg Gln Lys Leu Arg Leu 115 120 125 Trp Pro Thr Lys Glu Ala Asp Gly Gly Val Pro Thr Thr Pro Gly 130 135 140 Lys Val Pro Arg Asn Glu Arg Gly Glu Ile Glu Arg Leu Glu Arg Leu 145 150 155 160 Val Asn Lys Tyr Glu Arg Gly Gln Ile Gln His Val Asp Trp Leu Asp 165 170 175 Arg Leu Ala Phe Ser Ala Met Asp Lys Ala Met Glu Lys Glu Cys Glu 180 185 190 Arg Lys Ala Asn Leu Tyr Pro Ser Leu Val Val Glu Leu Cys Ser Phe 195 200 205 Glu His Arg Ile Val Phe Gln Glu Ser Gly Ala Asn Phe Tyr Thr Pro 210 215 220 Ala Pro Val Ser Leu Ser Asn Glu Leu Val Thr Val Trp Asp Pro Glu 225 230 235 240 Leu Gly Arg Thr Asn Pro Ser Glu His Lys Gln Leu Lys Leu Ala Lys 245 250 255	

	Ser	Leu	Thr	Arg	Gly	Ile	Val	Asp	Arg	Asp	Leu	Lys	Pro	Ser	Ser	Asn
	260			265							270					
	Glu	Arg	Lys	Leu	Leu	Gln	Thr	Ile	Ile	Lys	Phe	Pro	Pro	Thr	Arg	Thr
	275			280							285					
5	Leu	Glu	Val	Asp	Glu	Lys	Gln	Leu	Val	Trp	Lys	Phe	Arg	Phe	Ser	Leu
	290			295						300						
	Met	Ser	Glu	Lys	Lys	Ala	Leu	Thr	Lys	Phe	Val	Arg	Ser	Val	Asp	Trp
	305			310					315				320			
10	Ser	Asp	Asn	Gln	Glu	Ala	Lys	Gln	Ala	Val	Gln	Leu	Ile	Gly	Lys	Trp
	325			330					335							
	Glu	Met	Ile	Asp	Val	Ala	Asp	Ala	Leu	Glu	Leu	Leu	Ser	Pro	Asp	Phe
	340			345					350							
	Glu	Ser	Asp	Glu	Val	Arg	Gly	Tyr	Ala	Val	Ser	Val	Leu	Glu	Arg	Ala
	355			360					365							
15	Asp	Asp	Glu	Glu	Leu	Gln	Cys	Tyr	Leu	Leu	Gln	Leu	Val	Gln	Ala	Leu
	370			375					380							
	Arg	Phe	Glu	Arg	Ser	Asp	Lys	Ser	Arg	Leu	Ala	Leu	Phe	Leu	Val	Asn
	385			390					395				400			
20	Arg	Ala	Leu	Ser	Asn	Ile	Glu	Ile	Ala	Ser	Phe	Leu	Arg	Trp	Tyr	Ile
	405			410					415							
	Leu	Val	Glu	Leu	His	Ser	Pro	Ala	Tyr	Ala	Arg	Arg	Tyr	Tyr	Gly	Thr
	420			425					430							
	Tyr	Asp	Met	Leu	Glu	Asn	Ser	Met	Met	Lys	Leu	Val	Gly	Arg	Glu	Asp
	435			440					445							
25	Gly	Asp	Glu	Asp	Gly	Phe	Arg	Leu	Trp	Gln	Ser	Leu	Thr	Arg	Gln	Thr
	450			455					460							
	Asp	Leu	Thr	Ala	Gln	Leu	Cys	Ser	Ile	Met	Lys	Asp	Val	Arg	Asn	Val
	465			470					475				480			
30	Arg	Gly	Ser	Ala	Gln	Lys	Lys	Ile	Glu	Lys	Leu	Arg	Gln	Leu	Ser	
	485			490					495							
	Gly	Val	Phe	Ser	Glu	Leu	Thr	Asn	Phe	Asp	Glu	Pro	Ile	Arg	Ser	Pro
	500			505					510							
	Leu	Ala	Pro	Thr	Leu	Leu	Leu	Thr	Gly	Val	Val	Pro	Gln	Glu	Ser	Ser
	515			520					525							
35	Ile	Phe	Lys	Ser	Ala	Leu	Asn	Pro	Leu	Arg	Leu	Thr	Phe	Lys	Thr	Ala
	530			535					540							
	Asn	Gly	Gly	Thr	Ser	Lys	Ile	Ile	Tyr	Lys	Lys	Gly	Asp	Asp	Leu	Arg
	545			550					555				560			
40	Gln	Asp	Gln	Leu	Val	Ile	Gln	Thr	Val	Ser	Leu	Met	Asp	Arg	Leu	Leu
	565			570					575							
	Lys	Leu	Glu	Asn	Leu	Asp	Ieu	His	Leu	Thr	Pro	Tyr	Arg	Val	Leu	Ala
	580			585					590							
	Thr	Gly	Gln	Asp	Glu	Gly	Met	Leu	Glu	Phe	Ile	Ser	Ser	Ser	Ser	Leu
	595			600					605							
45	Ala	Gln	Ile	Leu	Ser	Glu	His	Arg	Ser	Ile	Thr	Ser	Tyr	Leu	Gln	Lys
	610			615					620							
	Phe	His	Xaa	Asp	Glu	Asp	Gly	Pro	Phe	Gly	Ile	Thr	Ala	Gln	Cys	Leu
	625			630					635				640			
50	Glu	Thr	Phe	Ile	Lys	Ser	Cys	Ala	Gly	Tyr	Ser	Val	Ile	Thr	Tyr	Ile
	645			650					655				655			
	Leu	Gly	Val	Gly	Asp	Arg	His	Leu	Asp	Asn	Leu	Leu	Thr	Asp	Asp	
	660			665					670							
	Gly	Arg	Leu	Phe	His	Val	Asp	Phe	Ile	Leu	Gly	Arg	Asp	Pro		
	675			680					685							
55	Lys	Pro	Phe	Pro	Pro	Pro	Met	Lys	Leu	Cys	Lys	Glu	Met	Val	Glu	Ala
	690			695					700							
	Met	Gly	Gly	Ala	Glu	Ser	Gln	Tyr	Tyr	Thr	Arg	Phe	Lys	Ser	Tyr	Cys
	705			710					715				720			
60	Cys	Glu	Ala	Tyr	Asn	Ile	Leu	Arg	Lys	Ser	Ser	Ser	Leu	Ile	Leu	Asn
	725			730					735							
	Leu	Phe	Lys	Leu	Met	Glu	Arg	Ser	Gly	Ile	Pro	Asp	Ile	Ser	Ala	Asp
	740			745					750							

Glu Ser Gly Gly Leu Lys Leu Gln Glu Lys Phe Arg Leu Asp Leu Asp
 755 760 765
 Asp Glu Glu Ala Ile His Phe Phe Gln Asp Leu Ile Asn Asp Ser Val
 770 775 780
 5 Ser Ala Leu Phe Pro Gln Met Val Glu Thr Ile His Arg Trp Ala Gln
 785 790 795 800
 Tyr Trp Arg

10 <210> 3
 <211> 22
 <212> DNA
 <213> Artificial Sequence

15 <220>
 <223> primer

<400> 3
 ccgcttctcc tcacacctct ct 22

20 <210> 4
 <211> 22
 <212> DNA
 <213> Artificial Sequence

25 <220>
 <223> primer

<400> 4
 30 tggcttgtga cagtcagcat gt 22

<210> 5
 <211> 1428
 <212> DNA
 35 <213> Zea mays

<220>

<221> CDS
 40 <222> (118)...(1176)

<400> 5
 cccgggtcga cccacgcgtc cgggtgcgg cccgcacaca ccacatgtcc cggctccgct 60
 ccgctccgcttcccttctc tcgggtgcgg ctactggct tcgctcggtc cggccgct atg 120
 45 Met 1

gtg tct ggc ggg tgc gtg ggg acg gag ggg gag gcg gac cgc gcg gcg 168
 Val Ser Gly Gly Cys Val Gly Thr Glu Gly Glu Ala Asp Arg Ala Ala
 50 5 10 15

gcg cct ccg gag gcc gcg gag gag ccg gtg gtg ccg gcg cct ccc gcg 216
 Ala Pro Pro Glu Ala Ala Glu Glu Pro Val Val Pro Ala Pro Pro Ala
 20 25 30

55 cgg gag gtc gtg gtg ggg tac gcg ctc acg acg aag aag gcc aag agc 264
 Arg Glu Val Val Val Gly Tyr Ala Leu Thr Thr Lys Lys Ala Lys Ser
 35 40 45

60 ttc ctc cag ccc aag ctc cgg ggg ctc gcc agg aaa aag gga atc ttg 312
 Phe Leu Gln Pro Lys Leu Arg Gly Leu Ala Arg Lys Lys Gly Ile Leu
 50 55 60 65

	ttt gtt gct att gat cag aaa cgt cca ttg tct gat caa ggt cca ttt Phe Val Ala Ile Asp Gln Lys Arg Pro Leu Ser Asp Gln Gly Pro Phe 70 75 80	360
5	gac att gtt ctt cat aag ttg act gga aag ggg tgg cag caa ttg ctg Asp Ile Val Leu His Lys Leu Thr Gly Lys Gly Trp Gln Gin Leu Leu 85 90 95	408
10	gag gaa tat agg gag gct cac cca gaa gtt act gtt ctt gat cca cct Glu Glu Tyr Arg Glu Ala His Pro Glu Val Thr Val Leu Asp Pro Pro 100 105 110	456
15	ggc gca ata gca aac ttg cta gat cgc caa tct atg ctt caa gaa gta Gly Aia Ile Ala Asn Leu Leu Asp Arg Gln Ser Met Leu Gln Glu Val 115 120 125	504
20	tct gaa ttg gac tca ccg att gtc atg ttc tct tct gca ggt aaa gta Ser Glu Leu Asp Ser Pro Ile Val Met Phe Ser Ser Ala Gly Lys Val 130 135 140 145	552
25	cgc gtg cct aaa cag cta ttc att aat act gat ccc tca tca ata cca Arg Val Pro Lys Gln Leu Phe Ile Asn Thr Asp Pro Ser Ser Ile Pro 150 155 160	600
30	gct gca gtt agg agg gcg ggt ctc tct ctc cca ttg gtg gca aaa ccc Ala Ala Val Arg Arg Ala Gly Leu Ser Leu Pro Leu Val Aia Lys Pro 165 170 175	648
35	ttg gtg gcg aag tcc cat gag cta tcc ctg gct tat gat cca act tca Leu Val Ala Lys Ser His Glu Leu Ser Leu Ala Tyr Asp Pro Thr Ser 180 185 190	696
40	ctg acc aaa ctt gag ccc cct tta gtt ctt cag gaa ttt gtt aac cat Leu Thr Lys Leu Glu Pro Pro Leu Val Leu Gln Glu Phe Val Asn His 195 200 205	744
45	gtt ggt gtc atg ttt aag gtg tac att gtt ggg gat gca ata agg gtt Val Gly Val Met Phe Lys Val Tyr Ile Val Gly Asp Ala Ile Arg Val 210 215 220 225	792
50	gta cgt cgg ttt tca ctt cca aat gtt gat gaa ggt gat ctg tcg aat Val Arg Arg Phe Ser Leu Pro Asn Val Asp Glu Gly Asp Leu Ser Asn 230 235 240	840
55	aat gct ggg gta ttt cgg ttt cca agg gtc tct tgt gct gca gcc agc Asn Ala Gly Val Phe Arg Phe Pro Arg Val Ser Cys Ala Ala Ser 245 250 255	888
60	gca gat gat gca gat ctt gac cct ggt gtt gct gaa ctt cct ccg aga Ala Asp Asp Ala Asp Leu Asp Pro Gly Val Ala Glu Leu Pro Pro Arg 260 265 270	936
	cca ttg ctt gag atc ttg gca cga gag ctg cgg cga cga ctg ggt ctt Pro Leu Leu Glu Ile Leu Ala Arg Glu Leu Arg Arg Arg Leu Gly Leu 275 280 285	984
	aga cta ttc aac att gat atg att agg gag cac gga aca aga gac cgg Arg Leu Phe Asn Ile Asp Met Ile Arg Glu His Gly Thr Arg Asp Arg 290 295 300 305	1032

	ttt tat gtc ata gac atg aac tac ttt cct ggg tac ggc aaa atg ccc	1080
	Phe Tyr Val Ile Asp Met Asn Tyr Phe Pro Gly Tyr Gly Lys Met Pro	
	310 315 320	
5	ggg tac gag cac gtg ttc acc gac ttc ctg ctg agc ctt gcc cag aaa	1128
	Gly Tyr Glu His Val Phe Thr Asp Phe Leu Leu Ser Leu Ala Gln Lys	
	325 330 335	
10	gag tac aag agg cga cca agc tat agc tcc cta ggc tca ggc gaa ggg	1176
	Glu Tyr Lys Arg Arg Pro Ser Tyr Ser Ser Leu Gly Ser Gly Glu Gly	
	340 345 350	
15	tgaaaagtga ggccgaggct actcgccggg ggtgcctgt atatgtctag catccgcaat	1236
	gcgtgcgtgc gtgcgtacag atgcgtgcg tgacggaga ggatgggtcg tagagttggg	1296
	gcacatgc atcacatcg tggccgcga aaaaagaagc gaggactgtt gataggctgt	1356
	aattaaatgg ttactttgca ggtgctaact gttcatgctt caaaaaaaaaa aaaaaaaaaa	1416
	aaaggcgcc cg	1428
20	<210> 6	
	<211> 353	
	<212> PRT	
	<213> Zea mays	
	<400> 6	
25	Met Val Ser Gly Gly Cys Val Gly Thr Glu Gly Glu Ala Asp Arg Ala	
	1 5 10 15	
	Ala Ala Pro Pro Glu Ala Ala Glu Glu Pro Val Val Pro Ala Pro Pro	
	20 25 30	
30	Ala Arg Glu Val Val Val Gly Tyr Ala Leu Thr Thr Lys Lys Ala Lys	
	35 40 45	
	Ser Phe Leu Gln Pro Lys Leu Arg Gly Leu Ala Arg Lys Lys Gly Ile	
	50 55 60	
	Leu Phe Val Ala Ile Asp Gln Lys Arg Pro Leu Ser Asp Gln Gly Pro	
	65 70 75 80	
35	Phe Asp Ile Val Leu His Lys Leu Thr Gly Lys Gly Trp Gln Gln Leu	
	85 90 95	
	Leu Glu Glu Tyr Arg Glu Ala His Pro Glu Val Thr Val Leu Asp Pro	
	100 105 110	
40	Pro Gly Ala Ile Ala Asn Leu Leu Asp Arg Gln Ser Met Leu Gln Glu	
	115 120 125	
	Val Ser Glu Leu Asp Ser Pro Ile Val Met Phe Ser Ser Ala Gly Lys	
	130 135 140	
	Val Arg Val Pro Lys Gln Leu Phe Ile Asn Thr Asp Pro Ser Ser Ile	
	145 150 155 160	
45	Pro Ala Ala Val Arg Arg Ala Gly Leu Ser Leu Pro Leu Val Ala Lys	
	165 170 175	
	Pro Leu Val Ala Lys Ser His Glu Leu Ser Leu Ala Tyr Asp Pro Thr	
	180 185 190	
50	Ser Leu Thr Lys Leu Glu Pro Pro Leu Val Leu Gln Glu Phe Val Asn	
	195 200 205	
	His Val Gly Val Met Phe Lys Val Tyr Ile Val Gly Asp Ala Ile Arg	
	210 215 220	
	Val Val Arg Arg Phe Ser Leu Pro Asn Val Asp Glu Gly Asp Leu Ser	
	225 230 235 240	
55	Asn Asn Ala Gly Val Phe Arg Phe Pro Arg Val Ser Cys Ala Ala Ala	
	245 250 255	
	Ser Ala Asp Asp Ala Asp Leu Asp Pro Gly Val Ala Glu Leu Pro Pro	
	260 265 270	
	Arg Pro Leu Leu Glu Ile Leu Ala Arg Glu Leu Arg Arg Arg Leu Gly	
60	275 280 285	
	Leu Arg Leu Phe Asn Ile Asp Met Ile Arg Glu His Gly Thr Arg Asp	
	290 295 300	

Arg Phe Tyr Val Ile Asp Met Asn Tyr Phe Pro Gly Tyr Gly Lys Met
 305 310 315 320
 Pro Gly Tyr Glu His Val Phe Thr Asp Phe Leu Leu Ser Leu Ala Gln
 325 330 335
 5 Lys Glu Tyr Lys Arg Arg Pro Ser Tyr Ser Ser Leu Gly Ser Gly Glu
 340 345 350
 Gly

10 <210> 7
 <211> 1059
 <212> DNA
 <213> Zea mays

15 <220>
 <221> misc_feature
 <222> (1)...(1059)
 <223> n = any base; n, y, r, h are as shown in WIPO
 Standard ST.25 (1998), Appendix 2, Table 1

20 <400> 7
 atggtnccng gnggntgygt nggnacngar ggnargcng aycgngcngc ncncncncn 60
 gargcngcng argarccngt ngtnccngcn cncncngcn gngargtngt ngtngntay 120
 gcncnacna cnaaraargc naartcntty ctngarccna arctncgngg nctngcncgn 180
 25 aaraarggna thctnttygt ngcnathgay caraarcgnc cnctntcnga ycarggnccn 240
 ttygayathg tnctncayaa rctnacnggn aarggntggc arcacrtntc ngargartay 300
 cngargcnc ayccnargt nacngtnctn gayccnccng gngcnathgc naayctnctn 360
 gaycgnacrt cnatgctnca rggngtntcn garctngayt cnccnathgt natgattytcn 420
 tcngcnggna argtncngt nccnaarcar ctnttyatha ayaacngaycc ntcntcnath 480
 30 ccngcngcng tnccnccngc ngnctntcn ctncnctng tngcnaarcc nctngtngcn 540
 aartcnccayg arctntcnct ncncntaygay ccnacntcnc tnacnaarct ngarcncn 600
 ctngtntnc argarttygt naaycaygt ggnctnatgt tyaargtnta yathgtnggn 660
 gaygcnathc gngtngtncg ncgncttctn ctncnccayg tngaygargg ngayctnctn 720
 35 aayaaygeng gngtnttycg nttyccnccn gtrtctngayt cngcngcnc ncngaygay 780
 gcnayctng aycnngngt ncngarctn ccncncngc cnctntcnga rathctngcn 840
 cngarctnc gncnccnct ngnctncgn ctnttyaaya thgayatgat hcngarcay 900
 ggnacncng aycgncttta ygtntayt atgaaytayt tccnngnta yggnaaratg 960
 ccnggntayg arcaygtntt yacngaytta ctncntcnc tngcncaraa rgartayaar 1020
 40 cngcngccnt ctntaytcntc nctngcncn ggnarggn 1059

<210> 8
 <211> 22
 <212> DNA
 <213> Artificial Sequence

45 <220>
 <223> primer

50 <400> 8
 ttctctcggt cgccgctact gg 22

<210> 9
 <211> 20
 <212> DNA
 55 <213> Artificial Sequence

<220>
 <223> primer

60 <400> 9
 aqcatgaaca gtttagcacct 20

Leu Pro Ile Val Asn Pro Asp Asp Ile Val Phe Gly Gly Trp Asp Ile
 130 135 140
 Ser Asn Met Asn Leu Ala Asp Ser Met Thr Arg Ala Lys Val Leu Asp
 145 150 155 160
 5 Ile Asp Leu Gln Lys Gin Leu Arg Pro Tyr Met Glu Ser Met Val Pro
 165 170 175
 Leu Pro Gly Ile Tyr Asp Pro Asp Phe Ile Ala Ala Asn Gln Gly Ser
 180 185 190
 Arg Ala Asn Ser Val Ile Lys Gly Thr Lys Lys Glu Gln Val Glu Gln
 10 195 200 205
 Ile Ile Lys Asp Ile Arg Glu Phe Lys Glu Lys Asn Lys Val Asp Lys
 210 215 220
 Ile Val Val Leu Trp Thr Ala Asn Thr Glu Arg Tyr Ser Asn Val Cys
 225 230 235 240
 15 Ala Gly Leu Asn Asp Thr Met Glu Asn Leu Leu Ala Ser Val Asp Lys
 245 250 255
 Asn Glu Ala Glu Val Ser Pro Ser Thr Leu Tyr Ala Ile Ala Cys Val
 260 265 270
 Met Glu Gly Val Pro Phe Ile Asn Gly Ser Pro Gln Asn Thr Phe Val
 20 275 280 285
 Pro Gly Leu Ile Asp Leu Ala Ile Lys Asn Asn Cys Leu Ile Gly Gly
 290 295 300
 Asp Asp Phe Lys Ser Gly Gln Thr Lys Met Lys Ser Val Leu Val Asp
 305 310 315 320
 25 Phe Leu Val Gly Ala Gly Ile Lys Pro Thr Ser Ile Val Ser Tyr Asn
 325 330 335
 His Leu Gly Asn Asn Asp Gly Met Asn Leu Ser Ala Pro Gln Thr Phe
 340 345 350
 Arg Ser Lys Glu Ile Ser Lys Ser Asn Val Val Asp Asp Met Val Ser
 30 355 360 365
 Ser Asn Ala Ile Leu Tyr Glu Pro Gly Glu His Pro Asp His Val Val
 370 375 380
 Val Ile Lys Tyr Val Pro Tyr Val Gly Asp Ser Lys Arg Ala Met Asp
 385 390 395 400
 35 Glu Tyr Thr Ser Glu Ile Phe Met Gly Gly Lys Asn Thr Ile Val Leu
 405 410 415
 His Asn Thr Cys Glu Asp Ser Leu Leu Ala Ala Pro Ile Ile Leu Asp
 420 425 430
 Leu Val Leu Leu Ala Glu Leu Ser Thr Arg Ile Gin Leu Lys Ala Glu
 435 440 445
 Gly Glu Asp Lys Phe His Ser Phe His Pro Val Ala Thr Ile Leu Ser
 450 455 460
 Tyr Phe Thr Lys Ala Pro Leu Val Pro Pro Gly Thr Pro Val Val Asn
 465 470 475 480
 45 Ala Leu Ala Lys Gln Arg Ala Met Leu Glu Asn Ile Met Arg Ala Cys
 485 490 495
 Val Gly Leu Ala Pro Glu Asn Asn Met Ile Leu Glu Tyr Lys
 50 500 505 510

50 <210> 12
 <211> 26
 <212> DNA
 <213> Artificial Sequence

55 <220>
 <223> primer

<400> 12
 ctcgctacct cgcttcgcat tccatt

60 <210> 13
 <211> 26

<212> DNA
 <213> Artificial Sequence
 <220>
 5 <223> primer
 <400> 13
 acgccacttg gctcacttgt actcca 26
 10 <210> 14
 <211> 3546
 <212> DNA
 <213> Zea mays
 15 <400> 14
 ctcgctaccc cgcttcgcattccattcgag gagagcggcg agaggggagg aaaggcaaga 60
 tggccatcgaa gagcttcgc gtcgagagcc cccacgtgcgtacggcc acggagatcg 120
 agtcggagta ccgggtacgac acgacggagc tggcacacga gggcaaggac ggcgcctcac 180
 gctgggtcggt ccgccccaaag tccgtcaagt acaacttccg gaccagaacc gccgtcccc 240
 20 agctcgggta tgcacggatg cagcggccct agcctcactc tctgtgaacc ctcctcc 300
 cgtgctcaagt caaatccctcc gtcgagatca actggtcggc gttccctccctaaatccta 360
 gaaaatctta ctgcttgcc tgaagacgaa ccgtcgtaat tggcacagc tacgcacaca 420
 cttgcccattc cggatgcgtc aaatcagatc gattgaaat tcgattcgat ggtgccttt 480
 tccatatttc gatcatccct cgcctactgt gcaatgatta cagaaacgtc ctttcctct 540
 25 gaactttgtc ttaggcttt tgcctgtgc acgtgagctg gtatcaattt gttcatgtaa 600
 gatcaaattc cagcaggagc gatgagcagc agacagaact cattacacta gcaaattgtat 660
 actaggatata ctggcaagtgc tgcatacggc gcaatctgcc atcctggacc ccctttgttt 720
 aattccctgtt cctatgcatttgcctacgt gcaagctcggtt gttgtttatg gtgtcaggct 780
 gtcagccgct tgcctgtgc cgcggatgatg tggcaacttt tctgttctgg tggcgcagg 840
 30 tggatgttgc ggggtgggaa ggcaacaacg ggtccacgct gacggctgg gtcattgcca 900
 acaggagatg agtagtactt aatttgcctt atattgtttt ccgttgcattt cagttattaa 960
 tggcctaaca gagaactgaa ttttgggtt ggttgcatttca gggatctca tggccgacca 1020
 aggacaagggt gcagcaagcc aactactacg gtcctcacc caggcctcca ccatcagagt 1080
 35 cggcagctac aacggggagg agatctatgc gccgttcaag agcctcccttc ccatggtaat 1140
 ctattataga ctgtactaat actcttcttt ttactgaaac caaacataca taacaaagca 1200
 tattccgtaa ggtgctagtt gatgttataa aatgaacctg tcttcagggc cagtggcttc 1260
 aagtaaacgg aatgttaatc attgggttga aaaaacaaag gttctaattt tggaaagga 1320
 aagttaaact tagcataatg aaaaggggaa gcactgtaaag aaaggtgctg aaacaatcga 1380
 40 ctcggctgc catgttgtga tcctacttgc aagtcaaaag gttctgttgt tagccaaag 1440
 gttccagcat ctttggatta cactcgtgca gtattgacga tgggtctaac tggcgcaga 1500
 ttcgcagact cgggtttgt tatcttcttt tcatgaccaa gtgtttaact ggtttcagg 1560
 tgaaccaga cgacattgtg ttcggaggct gggacattag caacatgaac ctggccgact 1620
 ccatgaccag gccaagggt ctggatatttgc acctgcagaa gcaagctcagg ccctacatgg 1680
 agtccatggc gcaacttccc cggtatctat gatccggact tcatcgcgc taaccaggc 1740
 45 tctcgcgcca acagtgtcat caagggcacc aagaaagaac agtggagca gatcatcaag 1800
 gatatcaggt atatggatat ggtgctaac gtccttgc gctaagggtgc acccagtgc 1860
 acctaaaaca aataaaact actatgaatt tggtaatatacatacatat cagagcatat 1920
 tggtaaccg qtgcacttag gagtctgc ggtatgtgg acaatttgcatttgc 1980
 cagtgaccgc tcacttgc gaggactcca caaagaacta aaactactga aagcttaagc 2040
 50 aactattcgt agctaattgtat gtattttgtt gacatggttt gaagatcttag attaacgtgg 2100
 ttgaagaaat atggtttact agtataagta atccattaca gaagcaatgg cttatgtac 2160
 taatgaaaca gggagtttag ggagaagaac aaagtggaca agatagttgt gttgtggact 2220
 gcaaacactg aaaggtatag caatgtgtgc gctggctca acgacacgttgg gagaatcta 2280
 ctggcatctg tggacaagaa cgaggcggag gtatcaccat caacactata tggcattgcc 2340
 55 tgggtcatgg aggggggtgc gttcatcaat gggagccccc agaacacctt tggcctgg 2400
 gcggtgtttg gttgtttgc aaaagctca tgggtttgc tttctgttcc aaagtttcat 2460
 ggtgtgtat ttctgttcca aggcttatta tacctgttgc atggtcgat ggtgttgc 2520
 tcttgcata aaaaacaact gcttgattgg tggtgacgac ttcaagatgttgg gacagacca 2580
 gatgaaatct gtccttgcg atttccttgc tggtgcttgc ataaagggtgg gacacactt 2640
 60 tctcttttcttca attaagatga agtgtttttt tggcaaatgc cgttattgc ataaactcttc 2700
 tatattttca ttttcatgca gcccacctca atcgtgagct acaaccactt gggaaacaac 2760
 gatggcatga acctgtctgc cttcaaaaca ttcaggttca aggagatctc caagagcaac 2820

5	gtggtggatg acatggtctc gagcaatgcc atcctctatg agcccgccga gcatcccgat catgtcggttgc tcatcaaggct ctgttagctg atctttcacc tcgttaaaaag ttgacatatg caaggcagat ttacattgaa acttgtcaact stttgttgc agtatgtgcc gtacgtggga gacagcaaga gggctatgga cgagtacacc tcagagatct tcattggcgg caagaacacc atcgtgctgc acaacacccctg tgaggatcg stcctcgccg cacctatcat cttgtatctg gtgctcttgg ctgagctcag caccaggatc cagctgaaag ctgagggagg ggttaagagcc ccccaaagtga ttaacctgaa agcacgctgc acgcttaggtg atatacgact tttaataacct tctgggtgtct ctcttatgca ggacaaattc cactccttcc acccggtggc caccatcctg agctacctca ccaaggcacc cttggtaagc sttttcttcc gcatcccgcc atcaactgcac tgcgttttgc ttcaatccag ccactgatcg tctctcttca aacctgaaca acaggttccc cctggcacac cggtggtgaa cgctctggcc aagcagacgg cgatgctgga gaacatcatg agggcctgctg cttggctggc cccagagaac aacatgatcc tggagtacaa gtgagccaag tggcgt	2880 2940 3000 3060 3120 3180 3240 3300 3360 3420 3480 3540 3546
10	<210> 15 <211> 3546 <212> DNA <213> Zea mays	
15	<400> 15	
20	ctcgctaccc cgcttcgcatttccattcgag gagagcggtg agagggagg aaaggcaaga tggtcatcgat gagcttcgc gtcgagagcc cccacgtgcg gtacggcccg acggagatcg agtcggagta ccgggtacgac acgacggagc tggtacacga gggcaaggac ggcgcctcac gctgggtcgt ccgccccaaag tccgtcaagt acaacttccg gaccagaacc gccgtcccc agctcgggttta tggatcgatg cagcggccct agcctcactc tctgtgaacc ctctcctcc cgtgctcagt caaatcctcc gtcgagatca actggtcggc gttcccttccaaatccta gaaaatctta ctgctttgcc tgaagacgaa ccgtcgtaat tggtgacagc tacgcacaca cttgcacccatc cggatgcgtc aaatcagctc gattgaaat tcgattcgat ggtgccctt tccatatttc gatcatcctt cgcctactgt gcaatgatta cagaaacgtc ccttcctct gaactttgtc ttaggcttt tgcctgtgc acgtgagctg gtatcaattt gttcatgtaa gatcaaattt cagcagggac gatgagcagc agacagaact cattacgcta gcaaattt actaggatta ctggcaagtg tgcatacggc gcaatctgcc atcctggacc ccctttgttt aattcctgtt cctatgcattt tgccctacgt gcagctcgat ttgtgttatg gtgtcaggct gtcagccgct tgcgtctgtc tgacggatga tgccaaacttt tctgttctgg tggtgcagg tgatgcttgc tgggtgggaa ggcaacaacg ggtccacgct gacggctggg gtcattgcca gcagggagtg agtagtactt aatttgcctt atattgcctt ccgttgcattt cagttattaa tggcctgaca gagaactgaa ttttgttgc ggctgttca gggatctca tggccgacca aggacaagggt gcagcaagcc aactactacg gtcctcacc caggcctcca ccatcagagt cggcagctac aacggggagg agatctatgc gccgttcaag agcctccttc ccatggtaat 40 ctattataga cttgactaat actcttctt ttactgaaac caaacataca taacaaagca tattccgtaa ggtgctagtt gatgttataa agtgaacctg tcttcaggc cagttgtctc aagtaaacgg aatgttaatc attgggttgc aaaaacaaag gttctaattt tggaaagga atgttaaact tagcataatg aaaagggaa gcattgttaag aaagggtctg aaacaatcga ctcggtctgc catgttgcattt tcctacttgc aagtcaaaag gttctgttgt tagctcaa 45 gttccagcat ctttggatta cactcgtgcgtt gattgacga tggtgctaact tggtgcaga ttcgcagact cgggtttgt tatcttcctt tcatgaccaa gtgttgaact ggttttcagg tggtttccaga cgacattgtg ttcggaggct gggacattag caacatgaac ctggccgact ccatgaccag ggccaagggtg ctggatattt acctgcagaa gcagctcagg cccacatgg agtccatggt gccacttccc cggtatctat gatccggact tcatcgccgc taaccagg 50 tctcgccca acagtgtcat caagggcacc aagaaagaac aggtggagca gatcatcaag gatatcaggt atatggatat ggatgctaact gtccttgcgt gctaagggtgc acccagtgc acctaaaaca aataaaatact actatgaatt tgtaaatat acatacatat cagaacatat tgtttaaccg gtgcacttag aagtctgcattt ggtatgttgc acaatttgcattt attcgatata cagtgaccgc tcacttgcattt gaggactcca caaagaacta aaactactga aagcttaagc 55 aactattcgt agctaattttt gttttttttt gacatgtttt gaagatctatg attaactgtgg ttgaagaaat atgggttactt agcataagta atccattaca gaagctatgg cttatgttagc taatgaaaca gggagttaa ggagaagaac aaagtggaca agatagttgt gttgtggact gcaaacactg aaaggtatag caatgtgtgc gtcgtctca acgacacgat ggagaatcta ctggcatctg tggacaagaa cgaggcggag gtatcaccat caacactata tgccattgcc 60 tggatcgatgg aggggtgcc gttcatcaat gggagccccc agaacacccctt tggccttgcgt gcgtggtttgc gtgtgttgc aaaagcttca tggatgttgc tttctgttcc aaagtttcat qgtgtttgtat ttccgttcca aqgcttattttt tacctgttgc atgttcgttag ggctgattga	60 120 180 240 300 360 420 480 540 600 660 720 780 840 900 960 1020 1080 1140 1200 1260 1320 1380 1440 1500 1560 1620 1680 1740 1800 1860 1920 1980 2040 2100 2160 2220 2280 2340 2400 2460 2520

	tcttgctata	aaaaacaact	gcttgattgg	tggtgacgac	ttcaagagtg	gacagaccaa	2580										
	gatgaaatct	gtcttggtcg	atttccttgt	tggtgctgga	ataaagggtgg	gaacctagta	2640										
	tctctttctt	attaagatga	agtgtttttt	tggcaaatga	cgttattgca	ataactcttc	2700										
5	tatattttca	tttcatgca	gcccacctca	atcgtgagct	acaaccactt	gggaaaacaac	2760										
	gatggcatga	acctgtctgc	cttcaaaaca	ttcaggtcca	aggagatctc	caagagcaac	2820										
	gtgggtggatg	acatggtctc	gagcaatgcc	atcctctatg	agcccgccga	gcatcccgat	2880										
	catgtcggttgc	tcatcaaggt	ctgttagctg	atctttcacc	tcgttaaaag	ttgacatatg	2940										
10	caaggcagat	ttacattgaa	acttgtca	cttttgttgc	atstatgtgcc	gtacgtggga	3000										
	gacagcaaga	gggctatgga	cgagtacacc	tcagagatct	atatggccgg	caagaacacc	3060										
	atcgtgctgc	acaacacctg	tgaggactcg	ctcctcgccg	cacctatcat	ccttgatctg	3120										
	gtgcttttgc	ctgagctcag	caccaggatc	cagctgaaag	ctgagggaga	ggtaagagcc	3180										
	ccccaaatgta	ttaacctgaa	agcacgctgc	acgcttaggtg	atatacgact	tttaataacct	3240										
	tctgggtgtct	ctcttatgca	gacaaaattc	caactccttcc	accgggtggc	caccatcctg	3300										
15	agctaccta	ccaaggcacc	cctggtaagc	cttttctctt	gcacccggc	atcaactgcac	3360										
	ttcggtttgc	ttcaatccag	ccactgatcg	tctctctcga	aacctgaaaca	acaggttccc	3420										
	cctggcacac	cggtggtgaa	cgctctggcc	aagcagacgg	cgatgctgga	gaacatcatg	3480										
	agggcctgcg	ttgggctggc	cccagagaac	aacatgatcc	tggagttacaa	gtgagccaag	3540										
	tggcgt						3546										
20	<210> 16																
	<211> 1070																
	<212> DNA																
	<213> Zea mays																
25	<400> 16																
	cggcacgagg	ttgcgggcga	accgaaaatc	acggggcgca	gagatcgagg	cacggcatgt	60										
	cggaggagca	tttcctcgcc	gtggcggtgg	aagccgc当地	gagcgccgdc	gagattattc	120										
	gcaaggaggatt	ctaccagacc	aagaacgtcc	agcacaagg	ccaggtggat	ttgtgtacgg	180										
30	agacggacaa	ggcctgcgag	gacctcatct	tcaaccacct	ccggaagcac	ttcccggacc	240										
	acaagttcat	cggggaggag	gagtccgcgg	cgctcgccgc	caccgctgac	ctcaccgacg	300										
	accccacctg	gatcgatcgat	cccctcgacg	ggaccactaa	tttgcgtccat	gtttccat	360										
	ttgtatgtgt	ctccgttggc	ctcaccattt	ggaaaattcc	cactgtcgga	gtcgcttca	420										
	accccatcat	gaacgaactt	ttcacggcgg	ttcgtggaaa	aggggcttcc	ctgaatggct	480										
35	ctccaattaa	agcatcatct	caagatgagt	tagtgaaggc	tcttctggta	acagaggctg	540										
	gaaccaatag	agacaagacc	actgtggatg	atacaacaa	cagaatcaac	aggctactat	600										
	acaagattcg	atccatacgg	atgtgtggat	cattggctt	aaacatgtgt	ggagttgcct	660										
	gtggtagact	agatttgtgt	tatgagatag	gatttgggtg	tccatggat	gttgctgctg	720										
	gtgctgtat	tcttcagggaa	gccgggtggcc	ttgttttga	cccaagcggc	ggagagttt	780										
40	atttgcgttgc	gcgaagaatg	gcaggatcaa	acagcttgc	gaaggataag	ttcgtcaagg	840										
	aactggggga	tactaattga	aacaaatgtt	agtattattc	gtggaacaga	ttaagacaat	900										
	aagggttgc	cggccgcattgg	tgattaactt	attgtttggg	caacaaaatt	ccatgttaatt	960										
	ctgcacctgt	acaactatgt	tggacgcaga	acattttatt	gagttttgt	attacatggg	1020										
	aatacatagg	ttgaggcaac	gttccctact	ttaaaaaaaaaa	aaaaaaaaaa		1070										
45	<210> 17																
	<211> 267																
	<212> PRT																
	<213> Zea mays																
50	<400> 17																
	Met	Ser	Glu	Glu	Gln	Phe	Leu	Ala	Val	Ala	Val	Glu	Ala	Ala	Lys	Ser	
	1						5		10						15		
	Ala	Gly	Glu	Ile	Ile	Arg	Lys	Gly	Phe	Tyr	Gln	Thr	Lys	Asn	Val	Gln	
							20		25						30		
55	His	Lys	Gly	Gln	Val	Asp	Leu	Val	Thr	Glu	Thr	Asp	Lys	Ala	Cys	Glu	
							35		40						45		
	Asp	Leu	Ile	Phe	Asn	His	Leu	Arg	Lys	His	Phe	Pro	Asp	His	Lys	Phe	
							50		55						60		
60	Ile	Gly	Glu	Glu	Ser	Ala	Ala	Leu	Gly	Ala	Thr	Ala	Asp	Leu	Thr		
	65						70				75				80		
	Asp	Asp	Pro	Thr	Trp	Ile	Val	Asp	Pro	Leu	Asp	Gly	Thr	Thr	Asn	Phe	
							85				90				95		

Val His Gly Phe Pro Phe Val Cys Val Ser Val Gly Leu Thr Ile Gly
100 105 110
Lys Ile Pro Thr Val Gly Val Val Phe Asn Pro Ile Met Asn Glu Leu
115 120 125
5 Phe Thr Ala Val Arg Gly Lys Gly Ala Phe Leu Asn Gly Ser Pro Ile
130 135 140
Lys Ala Ser Ser Gln Asp Glu Leu Val Lys Ala Leu Leu Val Thr Glu
145 150 155 160
Ala Gly Thr Asn Arg Asp Lys Thr Thr Val Asp Asp Thr Thr Asn Arg
165 170 175
10 Ile Asn Arg Leu Leu Tyr Lys Ile Arg Ser Ile Arg Met Cys Gly Ser
180 185 190
Leu Ala Leu Asn Met Cys Gly Val Ala Cys Gly Arg Leu Asp Leu Cys
195 200 205
15 Tyr Glu Ile Gly Phe Gly Gly Pro Trp Asp Val Ala Ala Gly Ala Val
210 215 220
Ile Leu Gln Glu Ala Gly Gly Leu Val Phe Asp Pro Ser Gly Gly Glu
225 230 235 240
Phe Asp Leu Met Ser Arg Arg Met Ala Gly Ser Asn Ser Leu Leu Lys
245 250 255
20 Asp Lys Phe Val Lys Glu Leu Gly Asp Thr Asn
260 265

25 <210> 18
<211> 25
<212> DNA
<213> Artificial Sequence

30 <220>
<223> primer

35 <400> 18
acgagggttgc gggcgaaccg aaaat 25

40 <210> 19
<211> 23
<212> DNA
<213> Artificial Sequence

45 <220>
<223> primer
<400> 19
tagggaccgt tgcctcaacc tat 23

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/14657

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6	C12N15/82	C12N15/55	C12N15/52	C12N15/54	C12N9/12
	C12N9/16	C12N9/90	C07K16/40	C12N1/10	A01H5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C12N C07K A01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 91 14782 A (MOGEN INT ;GIST BROCADES NV (NL)) 3 October 1991 cited in the application pages 5,7,15; examples 7,13 ---	27
X	SASAKI, T., ET AL. : "Rice cDNA from shoot, unpublished" EMBL SEQUENCE DATA LIBRARY, 9 March 1995, XP002082089 heidelberg, germany accession no.d47093 ---	1,2,6,9, 12,17
X	SASAKI, T. ET AL.: "Rice cDNA from shoot, unpublished" EMBL SEQUENCE DATA LIBRARY, 8 March 1995, XP002082090 HEIDELBERG, GERMANY accession no.d46351 ---	1,2,6,9
		-/-

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

Date of mailing of the international search report

26 October 1998

10/11/1998

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl.
Fax: (+31-70) 340-3016

Authorized officer

Holtorf, S

INTERNATIONAL SEARCH REPORT

1. National Application No

PCT/US 98/14657

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GILLASPY, G.E., ET AL.: "PLANT INOSITOL MONOPHOSPHATASE IS A LITHIUM-SENSITIVE ENZYME ENCODED BY A MULTIGENE FAMILY" THE PLANT CELL, vol. 7, December 1995, pages 2175-2185, XP002082091 abstract, Fig.1 + 2 ---	1-27
A	ISHITANI, M., ET AL. : "coordinate transcriptional induction of myo-inositol metabolism during environmental stress" THE PLANT JOURNAL, vol. 9, no. 4, 1996, pages 537-548, XP002082092 abstract: page 538; Fig. 1 + 8 ---	1-27
A	HONG.Z., ET AL. : "a phosphatidylinositol 3-kinase is induced during soybean nodule organogenesis and is associated with membrane proliferation" PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE USA, vol. 91, September 1994, pages 9617-9621, XP002082093 see the whole document ---	1-27
A	WILSON, M.P. AND MAJERUS, P.W.: "characterization of a cDNA encoding <i>Arabidopsis thaliana</i> Inositol 1,3,4,-trisphosphate 5/6-kinase" BIOCHEMICAL AND BIOPHYSICAL RESEARCH COMMUNICATIONS, vol. 232, no. 3, March 1997, pages 678-681, XP002082094 see figure 1 ---	1-27
P,X	LARSON, S.R. AND RABOY,V.: "linkage mapping maize and barley myo-inositol 1-phosphate synthase genes" EMBL SEQUENCE DATA LIBRARY, 5 May 1998, XP002082095 neidelberg, germany accession no. AF056326 -----	1,2,6,9, 12,15

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 98/14657

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.: 25, 26 because they relate to parts of the international Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
Claims 25 and 26 deal with sequence IDs that are not supported by the description.

3. Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking(Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

I. national Application No

PCT/US 98/14657

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO 9114782	A 03-10-1991	AU 649447	B	26-05-1994
		AU 7765691	A	21-10-1991
		AU 632941	B	14-01-1993
		AU 7776691	A	21-10-1991
		CA 2054762	A	24-09-1991
		CA 2056396	A	24-09-1991
		EP 0449375	A	02-10-1991
		EP 0449376	A	02-10-1991
		IL 97645	A	18-03-1997
		JP 6501838	T	03-03-1994
		JP 6502296	T	17-03-1994
		WO 9114772	A	03-10-1991
		PT 97110	A	29-11-1991
		PT 97111	A	31-12-1991
		US 5543576	A	06-08-1996
		US 5714474	A	03-02-1998
		US 5593963	A	14-01-1997
		US 5770413	A	23-06-1998